Long-term survival of dinoflagellate cysts in anoxic marine sediments.

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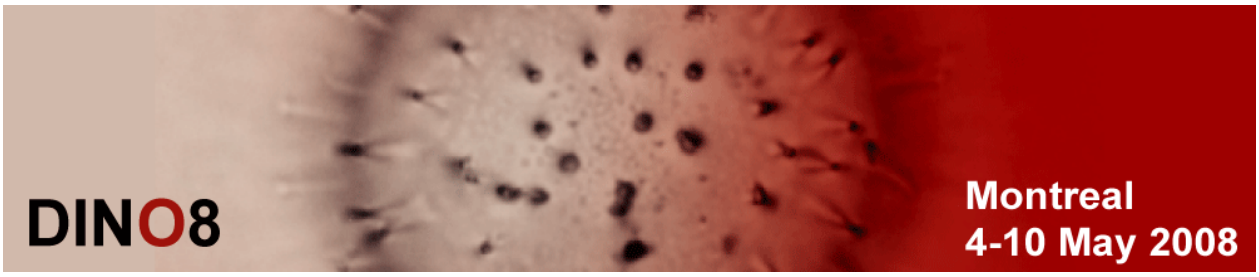

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Abstracts

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ABSTRACTS

Toxic blooms of *Alexandrium fundyense* in the Gulf of Maine: the role of cysts in population dynamics and long-term patterns of shellfish toxicity

Don Anderson, Bruce A. Keafer, Kerry Norton, Dennis J. McGillicuddy, Ruoying He, Cynthia H. Pilskaln, Darcie Couture and Jennifer L. Martin.

Resting cysts play important roles in bloom initiation, termination, and species dispersal for several important harmful algal blooms (HAB species). Several studies have examined linkages between dinoflagellate cyst abundance and bloom timing and location, but these efforts have typically been over relatively small areas due to the difficulties and expense of mapping cysts over larger regions. Here we present the results of five mapping surveys for living *Alexandrium fundyense* cysts in the Gulf of Maine, each covering hundreds of km in the alongshore direction, and 50 – 100 km in the offshore (see Figure 1). The first survey in 1997 (augmented with Bay of Fundy data from 1982, 1983 & 1984) revealed a widespread cyst distribution, with two centers of abundance, one in the Bay of Fundy, and a second offshore of Casco and Penobscot Bays in western Maine. The second survey (2004) shows a much larger cyst population, with approximately 10X as many cysts in the western Maine seedbed area. This was the cyst distribution that existed prior to, and undoubtedly contributed to, a massive 2005 *A. fundyense* bloom ("red tide") in southern New England. The third survey was conducted after the 2005 bloom, and reveals levels of cysts in western Maine that are ~5X the 1997 levels, but ½ of the 2004 levels. No significant geographic expansion of cysts into southern waters was seen, as had been feared based on the high motile cell concentrations that occurred in those waters during the 2005 bloom. The 2006 cyst map showed similar patterns to other years, with approximately 30% fewer cysts than observed in 2005. 2007 cyst abundance is 30% higher than the historically high levels observed in 2004. The overall pattern is thus one of large interannual variability, with an apparent increase in recent years.

Hindcasting studies using a physical-biological numerical model demonstrate that a major cyst deposition or accumulation event was the dominant factor leading to the large *A. fundyense* bloom in the western GOM and southern New England in 2005 and that cyst abundance in Gulf of Maine bottom sediments can be a first-order predictor of the magnitude of the resulting regional bloom. Monitoring of the regional abundance of cysts may thus hold the key to interannual forecasts of *A. fundyense* bloom severity in this region.

This presentation will discuss these interannual changes in the context of the blooms that occurred before and after the mapping efforts and the temporal trends in PSP toxicity in the region over the last several decades as well. Evidence will be presented in support of the hypothesis that we have entered a "new era" that is likely to have sustained and significant blooms in the coming years to decades. A cyst seedbed-based conceptual model will be presented that is consistent with observed patterns of interannual to decadal variability in the severity of blooms and shellfish toxicity in the Gulf of Maine.

Cyst-forming dinoflagellates and other phytoplankton species with resting stages are responsible for harmful algal blooms throughout the world. Our ability to map these stages and utilize those observations to initialize hindcasts and forecasts of bloom incidence is a major advancement in HAB management.

The role of resuspension in the nearshore cyst dynamics of *Alexandrium minutum* (Dinophyceae)

Sílvia Anglès, Esther Garcés, Antoni Jordi and Gotzon Basterretxea

Nearshore dinoflagellate blooms have recurrently occurred along the Mediterranean Sea since first blooms were reported back in the 60's. It is a growing problem often associated to cultural eutrophication that strikes with intensity in harbours, embayments, and coastal lagoons. Among other bloom forming species, *Alexandrium minutum* (Dinophyceae) is widely distributed in the Mediterranean Sea and events of paralytic shellfish poisoning (PSP) have been frequently associated with this species.

In the context of Mediterranean coastal blooms, water confinement is known to be a favouring factor from which *A. minutum*, benefits to produce extraordinary outbreaks with abundances often exceeding 106 cells l-1 and durations that can expand for months. Harbours, ports and other protection structures confine coastal areas where turbulence and advective exchange is artificially reduced. This is the case of Arenys de Mar harbor (NW Mediterranean), where recurrent blooms of *A. minutum* occurr every year since 1996. This

recurrence is favoured by the existence of resting cysts accumulated in the sediment floor.

During dormant stages, cyst abundances are determined by sediment conditions and dynamics. For example, similarly to the planktonic stages, natural mortality and grazing control cyst abundances in the sediment. Burial, reallocation within the substrate and sedimentary transport also determine cyst abundances. During the life stage transitions, evidence shows that burial in anoxic sediments, low temperature and presence of sulfides in the sediment can temporarily preclude mature cyst germination thereby controlling the bloom onset.

In the open sea maximum accumulation of dormant stages are often not right under the bloom shadow but in deep basins at the continental slope or in coastal areas. Conversely, in enclosed sites, relationships between planktonic and benthic stages are more straightforward. In general, accumulation of fine sediments in areas of reduced energy present higher cyst abundances suggesting that dormant stages behave as passive particles becoming part of the sediment dynamics. Although some of the aspects of the mechanisms that regulate the fate of cysts in the sediment can be anticipated based on their morphological characteristics (mainly size and density) most of the features of cyst dynamics remain to be elucidated.

In this study, we investigate the resting cyst dynamics of *A. minutum* in the Arenys de Mar harbor related to the seiching motion. Seiches are natural modes of oscillations at long periods in the range of one to several minutes, which play a key role on sediment resuspension in Arenys de Mar harbor.

Monitoring harmful microalgae in four municipalities in Pangasinan, Northwestern Philippines

Rhodora V. Azanza, Iris U. Baula and Yasuwo Fukuyo

Quarterly monitoring of harmful microalgae was conducted in 2006 in 8 stations covering four municipalities (Bolinao, Anda, Bani and Alaminos) in Pangasinan. Water samples were collected using a plankton net with 20 μm mesh, preserved with Lugol's solution and observed under a Zeiss Axioskop II microscope at 100x to 1000x.

The November and February sampling covered the northeast monsoon season. A diatom-dominated phytoplankton assemblage characterized this, particularly *Skeletonema costatum* and *Rhizosolenia* spp. In May which is the transition period from northeast to southwest monsoon season, a dinoflagellate-dominated phytoplankton assemblage was observed with few raphidophytes and cyanobacteria. *Alexandrium minutum*, a toxic microalgal species was observed during this time. In August, which is well into the southwest monsoon, two stations were dinoflagellate dominated while the rest were diatom dominated. These findings will be analyzed together with environmental factors and the presence of *Alexandrium minutum* cysts in these areas that may have contributed to such phytoplankton succession.

Taxonomic analysis of littke-known thecate planktonic dinoflagellates from the tropical Mexican Pacific

Sofia Barón-Campis, D. Hernandez-Becerril, C. Ramirez-Camarena, R. Rojas-Crisostomo and H. Ramirez-Garcia

Thecate dinoflagellates species of the genera *Ensiculifera*, *Fragilidium*, *Heterocapsa*, *Pentapharsodinium* and *Scripssiella* are marine and free-living, solitary forms, small-sized generally (less than 35 μm), which may produce calcareous cysts, some also may produce toxins and that are usually neglected in routine phytoplankton analysis. From the existing species of the five genera (5, 5, 12, 2 and 19, respectively, from a marine dinoflagellates's world list, Gómez, 2005), only 2 species of *Ensiculifera*, 2 of *Fragilidium*, 2 of *Heterocapsa*, 1 of *Pentapharsodinium* and 3 of *Scripssiella* have been recorded so far from the Mexican Pacific (following the recent list of dinoflagellates from the Mexican Pacific, Okolodkov and Gárate-Lizárraga, 2006). This work is based on the study of bottle and net (20 μm mesh) samples from a coastal zone from the mexican state of Oaxaca (South Pacific), with light and scanning electron microscopy. We have found species that are new records in the region, such as *Heterocapsa pygmaea* and *Scripssiella sweeneyae*, originally described from California, U.S.A. Other species include *Scripssiella spinifera* and *Scripssiella trochoidea*, the latter with a considerable morphologic variation (in other areas of the world it is associated with high genetic diversity and has raised questions on cryptic species, Montresor *et al*., 2003). Other species of the five genera already mentioned are also occurring in our samples, but to make positive identifications detailed studies are required (transmission electron microscopy observations and molecular biology studies). Calcareous cysts were not detected in this study. Key words: Dinoflagellates, Mexican Pacific, New

records, Phytoplankton, Scanning electron microscopy.

Modern dinoflagellate cysts from a mariculture area in Pangasinan, Northwestern Philippines

Baula Iris, Rhodora V. Azanza and Yasuwo Fukuyo

A mariculture area in Pangasinan, Northwestern Philippines has been plagued with yearly harmful algal bloom occurrences since 2001. The usual effects include massive fish kills that lead to huge economic losses for the townspeople. Studies on these HAB's have become more urgent when Paralytic Shellfish Poisoning cases were reported for the first time in the area in 2003 due to *Alexandrium minutum* and shellfish bans imposed seasonally in the subsequent years.

In this study, dinoflagellate cyst assemblage was determined from fifty-three stations which covered four municipalities in Pangasinan, namely Bolinao, Anda, Bani and Alaminos. Approximately fifty cyst types were identified which includes the toxic dinoflagellate *Alexandrium minutum*. Species that commonly occurred were *Spiniferites bulloideus*, *Algidasphaeridium minutum var. minutum* and *Brigantedinium majusculum*. Cyst concentration was low in every station which ranged from about 43 to 1940 cysts per gram dry weight. This can be attributed to the generally high organic loading, particularly of fish feeds in the area which dilutes dinoflagellate cyst assemblages. Areas of high cyst accumulation were found to be in the northern area (Bolinao) and the southern area (Anda) which could possibly serve as two point sources of *Alexandrium minutum* blooms. Factors that contribute to these accumulation sites will be discussed.

Late Holocene sea-surface conditions in the Fram Strait

Sophie Bonnet**,** Anne de Vernal, Claude Hillaire-Marcel and Bassam Ghaleb

One sediment core from the West Spitzbergen margin of the Fram Strait (78,92°N 06,77°E, water depth: 1497 m) was subsampled at 1-cm interval for palynological and geochemical analyses, with the objective to develop a high resolution record of hydroclimatic variations during the last two thousands years. The Fram Strait is the principal gateway between the Arctic and the North Atlantic oceans. It is a key area with respect to poleward heat transport through the North Atlantic Current and freshwater fluxes from the Arctic to the Atlantic.

The chronology of the 51 cm long core collected with the "multi-core" technique was established from ^{210}Pb and ^{137}Cs and ^{14}C measurements, which indicate a sedimentation rate of about 19 cm/kyrs and a mixing layer of roughly 5 cm. The studied sequence spans approximately 2400 years. Palynological analyses were performed for the study of dinocysts assemblages, which permitted the reconstruction of sea-surface conditions (summer and winter temperatures, salinity, sea-ice cover extent). We have used the best analogue method and a reference database that includes 1189 sites to reconstruct the past sea-surface conditions.

The dinocyst assemblages are dominated by *Operculodinium centrocarpum, Islandinium minutum, Nematosphaeropsis labyrinthus* and *Brigantedinium* spp. The accompanying species include *Spiniferites elongatus, Spiniferites ramosus, Spiniferites mirabilis-hypercanthus,* cyst of *Pentapharsodinium dalei, Selenopemphix quanta, Impagidinium pallidum* and *Impagidinium Sphaericum*. A principal component analysis (PCA) was done on taxa percentages. The first component (PC 1) explains 27.65% of the variance and the second component (PC 2), 16.48%. The proportion of taxa and the PCA permit to distinguish two assemblage zones from 2400 to 640 yrs BP (i.e. 450 BC to 1310 AD) and from 640 to 80 yrs BP (i.e. 1310 AD to 1870 AD). The dinocyst assemblages indeed mark a clear transition at about 640 yrs BP with the disappearance of the thermophilic taxa *Spiniferites mirabilis-hypercanthus*, *Selenopemphix quanta* and *Impagidinium sphaericum* and the increase percentages of the polar-subpolar taxa *Impagidinium pallidum* and *Pentapharsodinium dalei*. This change corresponds to the Medieval Warm Period - Little Ice Age transition. On the average, the sea-surface temperatures are superior to the modern values until 640 yrs BP although three cooling pulses are recorded around 1900, 1550 and 900 yrs BP (i.e. 50, 400 and 1050 AD, respectively). From 640 to 80 yrs BP, there is a cooling trend marked by a decrease of summer temperatures from 7°C to 2°C and spreading of sea-ice cover up to 7 months/year. In the Fram Strait, the recent warming conditions of the last decades have no analogue in the last 2000 yrs, except a warm optimum centered at about 1350 BP (i.e. 600 AD).

Palynological evidences for climatic and oceanic variability off NW Africa during the late Holocene

Ilham Bouimetarhan, Lydie Dupont, Enno Schefuß, Gesine Mollenhauer, Stefan Mulitza and Karin Zonneveld

Pollen and organic-walled dinoflagellate cyst assemblages from core GeoB9503 retrieved from the mud-belt (50 m water depth) off the Senegal River mouth have been analyzed to reconstruct short-term paleo-oceanographic and paleo-environmental changes in tropical NW Africa during the interval from 4200 to 1200 years before present (BP). Our study emphasizes significant coeval changes in continental vegetation and oceanic environmental changes in and off Senegal. The land-sea correlation is further examined by comparison with paleo-sea surface temperature (SST) reconstructions based on alkenones analyses. These multi-proxy analyses reveal short-term land-sea climatic linkages in the western Sahel during the late Holocene.

Initial dry conditions were followed by a strong and rapid humidity increase around 2900 years BP when the environment became enriched in woody plants and plants requiring wet conditions. This interval is also characterized by the occurrence of dinoflagellate cysts of river plume affinity. We interpret these observations as the result of enhanced Senegal River runoff with high terrigenous input into the ocean and the local occurrence of cool and less-saline surface waters suggesting discharge-induced upwelling off the river mouth. After 2,500 years BP, the environment slowly became drier again, as indicated by slight increases in sahelian savanna and desert elements. Around 2200 years BP, strong fluctuations in pollen and dinocyst accumulation rates in conjunction with periodically lowered SSTs, suggest an episodic 'flash flood' events of the Senegal River. The driest phase developed after about 1,800 years BP characterized by the decrease of arboreal pollen and its replacement by pollen from the Saharan group and occurrence of pollen of *Pinus* and *Olea* that have their source areas in North Africa suggesting strong trade winds. Furthermore, high abundances of dinoflagellate cysts of subtropical/tropical affinity, such as *Tuberculodinium vancampoae* and *Lingulodinium machaerophorum*, indicate high nutrient, warm and stratified surface water conditions over the core site.

Distribution of organic-walled dinoflagellate cysts and pollen in marine surface sediments off NW Africa in relationship to environmental conditions

Ilham Bouimetarhan, Lydie Dupont, Karin Zonneveld and Fabienne Marret

Surface sediment samples from thirty-five sites off NW Africa have been investigated on their palynological content in order to obtain insight in the spatial distribution of quantitative organic-walled dinoflagellate cysts (dinocysts), pollen/spores and that of other palynomorphs in relation to the local environmental conditions.

Multivariate ordination analysis has been carried out on the relative abundances of dinocysts species to investigate the relationships between their distribution patterns in the marine sediments and the environmental parameters of the upper water column. Also sediment transport processes are taken into account.

The distribution of pollen and pteridophyte spores in marine sediments is used as an indicator for terrestrial conditions recording source areas of pollen and spores and the effect of different transport mechanisms.

Evolution of sea surface parameters on the Mackenzie slope (Beaufort Sea, Canadian Arctic) over the last 4000 years: context, problematics and methods

Manuel Bringué and André Rochon

Since global climate change threatens to change the face of Earth, the study of Arctic oceanic and atmospheric components is now believed to be of uppermost importance in the understanding of past, present and future climatic variations in a context of global warming.

My master's project aims at reconstructing the evolution of paleoceanographic parameters over the Mackenzie slope (Beaufort Sea, Canadian Arctic) during the last 4000 years. The evolution of these parameters (temperature, salinity, duration of sea ice cover, productivity) will be assessed from dinocyst assemblages preserved in the sediments (station 2004-804-803, sampled in 2004 aboard the CCGS Amundsen). The purpose of this poster is to present the context of my research project (e.g. find evidence of similar warming events over the past 4000 years), and the methods used for paleoclimatic reconstructions based on dinocyst assemblages as proxy indicators. A brief paleoceanographic context of the Arctic Ocean is also presented.

The coring site lies at 220 meters water depth, close to the Mackenzie delta. The proximity of both the main Arctic sediment input (the Mackenzie River) and the anticyclonic Beaufort gyre suggests that the core may contain useful information on past oceanographic processes and freshwater/sediment inputs in the Mackenzie Shelf area. In addition, wavelet and spectral analyses on paleosignals, such as freshwater algae and dinocyst abundances, will be performed in order to detect cycles in Arctic's climate variability. Our results will also be compared with similar studies from the Beaufort Sea, Canadian Arctic Archipelago, Chukchi Sea, as well as paleoenvironmental studies conducted on adjacent landmasses.

Drilling the Arctic Palaeogene swamp: a dinoflagellate perspective

Henk Brinkhuis, Francesca Sangiorgi, Appy Sluijs, Stefan Schouten and the ACEX Science Party

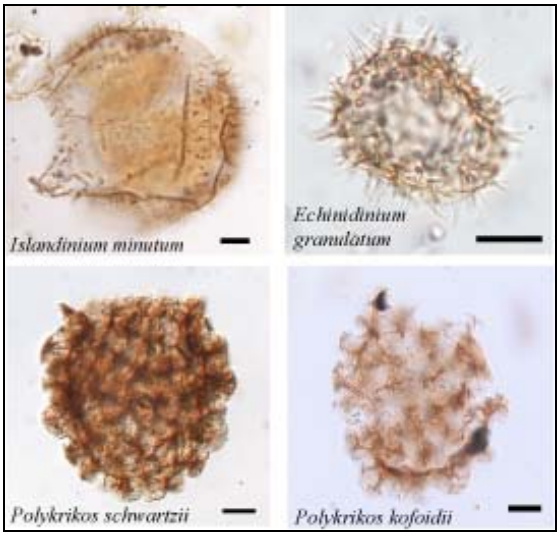
In September 2004, the first-ever drilling of the Lomonosov Ridge (Arctic Coring Expedition, ACEX, or IODP Expedition 302) recovered unprecedented climate records of the central Arctic Ocean spanning the past ~56 Ma. Age-assessment, largely based on dinoflagellates, includes the recognition of some ~200m each of upper Neogene, and middle Palaeogene deposits, with a conspicuous ~26 Ma hiatus separating these units. The Neogene record has relatively low sedimentation rates and perennial glacial conditions starting from 14 Ma. Contrastingly, the Palaeogene is a story of waxing and waning of freshwater influence, warm conditions, and relatively high accumulation rates of organic-rich sediments. Palynological analyses have revealed the successful recovery of the Paleocene - Eocene transition, with the occurrence of an *Apectodinium augustum* acme at the Paleocene Eocene Thermal Maximum (PETM) some 55.5 Ma ago. This finding contrasts predictions, which had placed the base of the sediment column, above Cretaceous basement, at 50 Ma. During the PETM our dinocyst and TEX_{86} palaeothermometer records show combined increased runoff and sea level rise and a subtropical Arctic Ocean, with temperatures of ~23ºC. Other Palaeogene highlights also include the recovery of the Eocene Thermal Maximum 2 (aka ELMO ~53.5 Ma). Dinocyst assemblages show a freshening of Arctic Ocean surface waters, while TEX_{86}-derived paleotemperatures rise from ~18 – ~22 °C. At the early – middle Eocene transition (~49 Ma) stunning concentrations of remains of the fresh water fern *Azolla* and freshwater tolerant dinocysts suggest that, at least episodically, completely fresh surface water settings characterized the Arctic Basin. During the middle Eocene, shifts in salinity and in ice rafted debris follow a strong cyclical, orbitally driven pattern. Moreover, dinocyst stratigraphy was instrumental in recognizing and assessing the ~26 Ma hiatus, which marks the transition from the greenhouse world to the icehouse world. Above the hiatus, a new Miocene dinocyst genus *Arcticacysta* and higher then expected sea surface temperatures (15-19 ºC) mark the recovery of sedimentation on the Lomonosov Ridge near the Miocene Climatic Optimum.

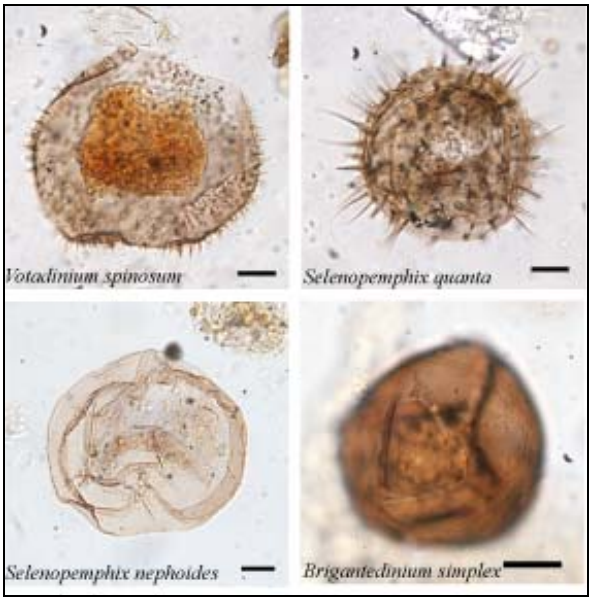
Dinoflagellate cyst assemblages of surface sediments from the Beagle Channel, Tierra del Fuego, Argentina – preliminary results

Soledad Candel, Taoufik Radi and Anne de Vernal

Palynological analyses of nine surface sediment samples from the restricted area of the Beagle Channel, Tierra del Fuego, Argentina, were performed in order to investigate the distribution of dinoflagellate cyst assemblages in high latitudes of the Southern Hemisphere and to explore their relationships with sea-surface conditions.

Preliminary results show relatively low dinocyst concentrations compared to high latitudes of the Northern Hemisphere. However, dinoflagellate cyst assemblages have relatively high species diversity with 23 taxa identified. Results show also that the assemblages are mostly composed by Protoperidiniale taxa and are dominated by *Brigantedinium* spp, *Echinidinium* spp and *Selenopemphix quanta* accompanied notably by cysts of *Pentapharsodinium dalei*, *Echinidinium granulatum, Islandinium minutum, Votadinium spinosum, Polykrikos kofoidii, and Polykrikos schwartzii*. Such assemblages show some similarities with those of high latitudes regions of the Northern Hemisphere. However, some taxa, previously suggested as exclusive to warm environments occur with relatively high percentages in the Beagle Channel (e.g. *Echinidinium* spp. and *Votadinium spinosum*).





Writing a dinoflagellate guidebook

Susan Carty

Anyone who has tried to use morphological characters to identify a dinoflagellate (and everyone eventually has to) knows how difficult it is. The difficulties stem from the organisms themselves, difficulty in locating keys, and changes and confusion with names. As a birder myself, it seems to me the field guide format might serve as a useful model for a dinoflagellate guidebook. For convenience, this guidebook is limited to North America and contains illustrations of all reported species (line drawings of all, and light and scanning electron micrographs of many), distribution maps, and descriptions. There has been no compilation of freshwater dinoflagellate species for North America since the works of Eddy (1930) and Wailes (1934). Using my own collections (about 1500 samples from 23 states in the United States and Belize) and the literature (13 provinces in Canada, 49 states in the U.S., Mexico, Greenland, Costa Rica, Guatemala, Panama, Cuba, Jamaica, Puerto Rico, Barbados, Guadeloupe) have provided me with the information for the guidebook. Currently there are 120 species in 39 genera, 12 of which were new species reports from North America and 30 of which are single reports. The process of assembling this book has shown some large gaps in our knowledge of freshwater dinoflagellate species distribution and will hopefully make "dino" identification easier for future workers.

DMS and DMSP production by dinoflagellates - is plastid type the key?

Amandine Caruana, Sue Turner, Michael Steinke and Gill Malin

The biogenic gas DMS (dimethylsulphide, CH_3-S-CH_3) is the main natural sulphur compound emitted from the ocean to the atmosphere. As well as being a key compound in the natural sulphur cycle, DMS has the potential to cool the climate because its atmospheric oxidation products create aerosols that may act as nuclei for cloud condensation, and aerosols and clouds attenuate solar radiation thereby reducing temperature at the Earth's surface (Fig. 1).

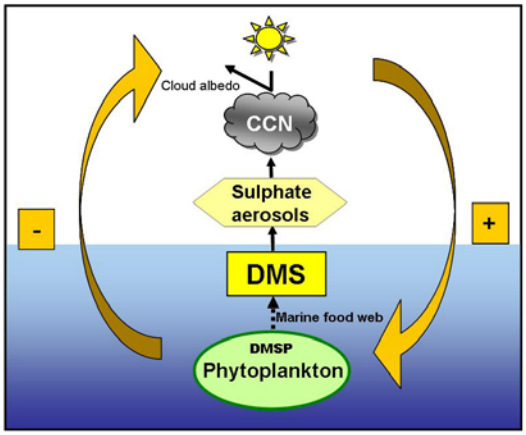


Figure 1: the CLAW hypothesis describing the climate-phytoplankton feedback interaction through DMS.

DMS derives from the degradation of DMSP (dimethylsulphoniopropionate, $(CH_3)_2S^+CH_2CH_2COO^-$)

which is synthesised by some types of algae. Phytoplankton release DMSP during cell lysis induced by senescence, grazing and viral infection, and DMSP can be broken down into DMS by algal and bacterial enzymes. A range of cellular functions have been reported for DMSP suggesting roles as an osmolyte, a cryoprotectant, an antioxidant and a chemical defence against grazers, but none of them has been generalised to all producers. Dinoflagellates are considered one of the major DMSP producing phytoplankton groups but surprisingly our understanding is quite limited. Dinoflagellates are also changing in abundance with climate-related increases in seawater temperature and this affects marine community structure. Therefore it is crucial to investigate how this group will evolve in the context of global warming, how DMSP producers will be affected and in turn affect climate. Published data on DMSP content suggests a high variability between dinoflagellates species. This variability might be due to the use of different analytical techniques, the difficulties associated with comparing laboratory and field data and, perhaps more importantly inter- and intra-specific variability. Our starting point for this project was to explore the role of the plastid type in DMSP production. In the flowering plant *Wollastonia biflora*, one of the few land plants that make DMSP, DMSP is synthesised in the chloroplasts and this is assumed to be the case in phytoplankton. Furthermore, dinoflagellates have a fascinating plastid evolution (Fig. 2) and are the unique taxon which contains 5 plastid groups (peridinin, haptophyte-like, diatom-like, cryptomonad-like, prasinophyte-like plastids) and a heterotrophic group without functional plastid.

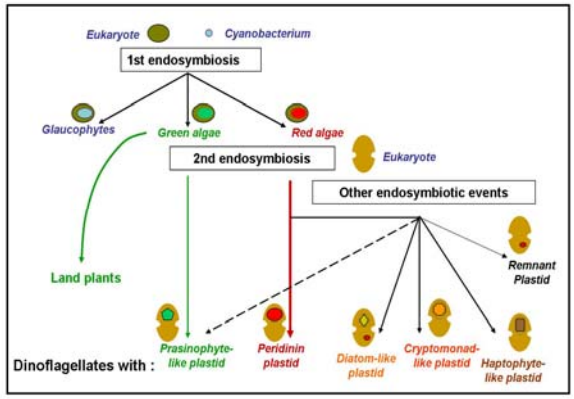


Figure 2: Plastid evolution in dinoflagellates

Here, we gather and compare for the first time published data on DMSP measurements in dinoflagellates. Moreover, we show our laboratory results (Fig. 3) which compare DMSP production between species using identical methods. Three species *Heterocapsa triquetra, Karlodinium micrum and Crypthecodinium cohnii* are examined, each one harbouring a different plastid type peridinin plastid, haptophyte-like plastid and remnant plastid respectively. Laboratory cultures were monitored during growth curve experiment and cell density and total DMS and DMSP (TDMSP) production were measured. Production ability between species varies by 2 orders of magnitude and maximum production occurs at different growth phase depending on the species. This might suggest that DMSP fulfils different biological needs in different species and that dinoflagellate populations could show maximum production at different bloom stages.

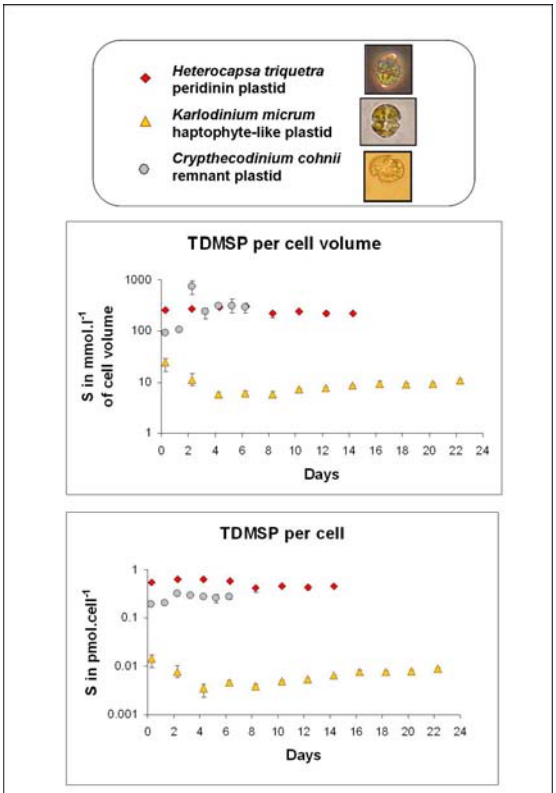


Figure 3: Interspecific comparison of TDMSP production between 3 dinoflagellates species

Non indigenous dinoflagellate cysts: from ballast sediments to Canadian aquatic ecosystems

Oscar Casas-Monroy, Suzanne Roy and André Rochon

The present study examines dinoflagellate cysts species found in Ballast sediments carried by

ships visiting the Canadian West and East coast and the Great Lakes. The purposes are to identify and to quantify dinoflagellate cysts species from ballast sediments and to determine propagule pressure between transoceanic ships, USA exchanged and USA unexchanged ballast water. In summer 2007, 131 ships were samples in these regions and 68 samples of sediment were taken in the most forepeak tanks of vessels. Dinoflagellate cysts were identified and counted using inversed microscopy. Live dinoflagellate cysts were cultured to assess their potential for establishment. For the East coast, abundances of cysts varied between 0.15 and 26.4 cysts cm^{-3}. The most abundant species were *Brigantenium* sp (26.4 cysts cm^{-3}), *Bitectatodinium tepikiense* (21.1 cysts cm^{-3}), *Polykrikos schwartzii* (6.1 cysts cm^{-3}) and *Operculodinium centrocarpum* (4.8 cysts cm^{-3}). Three non indigenous species were found in these samples: *Fragilidium* cf *mexicanum, Gymnodium* cf *catenatum* and *Lingulodinium machaerophorum*. For the germination tests, 82 dinoflagellate cysts from different species were cultured, 35 of them did not germinate, and we observed successful cyst germination for 20 of them. In these experiences, any non indigenous were not germinated. The abundance, diversity and propagule pressure will be compared between both coasts and the Great Lakes.

Late Mesozoic dinoflagellates during the marine transgression in Heilongjiang, NE China

Wan Chuanbiao, Gao Ping, Li Yanfeng, Wang Qingyuan, Xue Yunfei

Upper Mesozoic sediments of Heilongjiang, Northeast China, show abundant dinocysts including both fresh-water and marine dinocysts. Based on the studies of over thousand of samples from the six main sedimentary basins of Heilongjiang, NE China, 21 dinocysts assemblages are recongnized for the Jurassic and Cretaceous deposits, among them, 5 assemblages might be related to the marine transgressive events during the Late Mesozoic. They are:

1. *Pareodinia ceratophora - Chytroeisphaeridia scabrata* assemblage. This assemblage represents the Middle Jurassic marine transgressive event, is rich in *Pareodinia ceratophora* and *Chytroeisphaeridia scabrata* and characterized by *Nannoceratopsis pellucida*. Other important taxa are: *Rhynchodiniopsis* cf. *cladophra*, *Leptodinium arcuatum*, *Letodinium* sp., *Cribroperidinium* sp., *Endoscrinium* cf. *campanula*, *Pareodinia suibinensis*, *Sentusidinium asymmetricum*, *Diconodinium ellipticum*, *Fromea complicate* and *Evansia perireticulata*. All of them are marine dinoflagellates found from the Suibin Formation of Suibin, eastern Heilongjiang, which is dominated by paralic swamp coal-bearing deposits. The age of this assemblage is Callovian of Middle Jurassic (He Chengquan, et al., 1997).

2. *Gonyaulacysta jurassica - Amphorula delicate* assemblage. This assemblage represents the late Jurassic marine transgressive event, found from the Dongrong Formation of Suibin. The lower part of the assemblages is dominated by *Gonyaulacysta jurassica* (over 95% of all species), and the paragenetic molecules are: *G. helicoidea*, *G. dualis*, *Occisucysta elongata*, *Rigaudella aemula*, *Chytroeisphaeridia suibinensis*, *Trichodinium castanea*, *Apteodinium frontierense*, *Tubotuberella* sp. and *Scriniodinium* sp. The age of this part is late Oxfordian - early Kimmeridgian. The upper part is dominated by *Amphorula delicate* which is companied by *Endoscrinium galeritum* and *Gonyaulacysta jurassica* (Sun Xuekun et al., 1992). The age of the upper part might be Tithonian.

3. *Oligosphaeridium complex* assemblage. This assemblage represents the early Cretaceous marine transgrassive event, characterized by abundant *Oligosphaeridium complex.* The other important elements of this assemblage include *Oligosphaeridium albertense*, *O. pulcherrimum*, *O. anthophoprum*, *O. dictyophorum*, *O. perforatum*, *Occisucysta evittii*, *Hystrichosphaeridium arborispinum* and *Systematophora complicate*. These elements show marine littoral or neritic environments and Valanginian-Hauterivian in age. The transgressive scale at this moment is much larger than that in late Jurassic.

4. *Kiokansium* sp. - *Dinogymniopsis* sp. assemblage. This assemblage might represent the mid-Cretaceous marine transgrassive event, found in the base member of Qingshankou Formation in Songliao basin, Northeast China. Abundant and various slight brackish or semi-brackish algal fossils are included in this assemblage. Among them, *Filisphaeridium* sp., *Operculodinium capituliferum*, *Kiokansium regulatum*, *K. dclinatum* might be the ecological equivalents of marine dinoflagellates after the short period adaptation in the desalination water. More than ten species of calcium ultramicrofossils are also found in the base member of the formation (Ye Shufen et al., 1996), which probably came from the paleo-pacific ocean during the transgression. The age of this assemblage is Cenomanian.

5. *Cleistosphaeridium nenjiangenses* assemblage. This assemblage may indicate the late Cretaceous marine transgressive event, found from the No.1 and No.2 members of Nenjiang Formation in Songliao basin, characterized by abundant

Cleistosphaeridium nenjiangenses which is accompanied by coccolithes, littoral bivalves, fishes and sharks. The age of this assemblage might be Companian.

Acknowledgments:
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Pfiesteriaceae: a successful dinoflagellate group also in freshwater

Sandra Carla Craveiro, António José Calado, Niels Daugbjerg and Øjvind Moestrup

The family Pfiesteriaceae was formally described in 1996 to accommodate the new genus *Pfiesteria*, a fish-killing dinoflagellate that attracted unprecedented attention from the general public. The original defining features of the family were centered on a complex, multiphasic life cycle, which included flagellate, amoeboid and cyst stages. This set of characters made the group rather exclusive in the sense that other dinoflagellates with features that would fit the new group could not be found. However, the following years saw the description of new species of Pfiesteriaceae, for which a multiphasic life cycle could not be demonstrated, placing the emphasis on the characters of the flagellate stage, especially the feeding mode and the tabulation of the theca. The flagellate, thinly thecate cells became known as 'cryptoperidiniopsoids', in allusion to the peridinioid type of tabulation found in members of *Peridiniopsis*. The recently demonstrated affinity of the parasitoid marine dinoflagellate genus *Paulsenella* to *Pfiesteria* and *Amyloodinium* highlights the feeding mode as a good phylogenetic marker for the group. The feeding-related features, including the fine structure of the feeding apparatus, known from members of the *Pfiesteria* clade closely match the ones described from the freshwater heterotrophic dinoflagellate currently known as *Peridiniopsis berolinensis*; and the tabulation of this species shows clear analogies to the tabulations of *Pfiesteria*, and the recently described *Pseudopfiesteria* and *Cryptoperidiniopsis*. Partial LSU-rDNA sequences confirm the close affinity between *P. berolinensis* and *Pfiesteria*. Although often unnoticed, *P. berolinensis* is one of most common freshwater dinoflagellates, capable of surviving on a large variety of protist and even metazoan prey. The fine structure of the species, in particular features of the flagellar apparatus, suggest a closer affinity to other peridinioids than currently proposed for the Pfiesteriaceae.

Dinoflagellate cysts in sediments as indicators of productivity, upwelling and eutrophication: sorting out the signals

Barrie Dale

This presentation reviews the main ways in which cysts in sediments have been used as indicators of productivity, upwelling and eutrophication. The main topics addressed include:

1) Limitations that must be acknowledged in attempts to use cysts as indicators of productivity: cyst concentration in sediments is affected by cyst production (variable between species and within a species?); sedimentation (rates vary between sample sites, and at a given site with variable run-off, e.g. due to climatic variation in precipitation or human pollution); and sediment mixing (bioturbation and human activities).

2) Methods – theoretically, fluxes of cysts (amounts /unit of time) offer the most accurate approximation of cyst production, but in most cases dating of sediments is a limiting factor (frequency of measurements within a core, error margins of actual measurements, etc.). The wet sediment volumetric method is flawed – cyst concentrations are affected by water content of sediment, an added parameter independent of production. In most cases, the cysts/g dry sediment offers the best standardised method of estimating cyst concentrations through a core, but, for reasons discussed, this cannot be taken as a true measure of productivity. However, this method has proved successful in identifying changes that seemingly can be related to changes in productivity, when other factors are considered.

3) Transfer function methods using diatoms in sediments are used in lakes as indicators of productivity, and may also prove useful for cysts in lakes, and possibly in hydrographically restricted

coastal basins. Attempts to use these methods for cysts in the deeper water, open sea, will be subject to the same criticism as earlier attempts to develop paleoenvironmental indicators (ecologically unrealistic due to cyst transport, etc.).

4) The concept of interpreting cyst-based productivity signals from marine sediments has proved useful for tracing paleo-upwelling and coastal eutrophication. Two main signals are recognised based on increased amounts of *Lingulodinium*, and at least a proportional increase in cysts of heterotrophic versus autotrophic species. The validity of these signals has been strengthened by work carried out by various authors since the signals were first described. Nonetheless, objections have been raised: e.g. How can we use *Lingulodinium* as a eutrophication indicator in some cases, and as a climatic indicator in others?; and is the heterotroph signal caused by selective oxidation of less resistant cysts versus their selective preservation in low oxygen sediments at sites with high productivity? The critical question is whether we can sort out the different environmental signals in our cyst assemblages, in order to make meaningful interpretations related to productivity. The case is made that indeed we can – illustrated by some of our latest work showing that the collapse of local fisheries at different times along the Norwegian coast within the past 50 years is related to local eutrophication reinforced by climatic influence. This was deduced from cyst records from cored sediments in the affected systems.

The dinoflagellate cyst perspective on the Pliocene–Pleistocene transition in the North Atlantic

Stijn De Schepper

The Pliocene was the last time when global climate was warmer than today. The intensity of sunlight incident on Earth, the land–sea distribution, and atmospheric carbon dioxide concentrations were close to what they are today, but surface temperatures in polar regions were so much higher during the mid-Pliocene that continental glaciers were absent from the Northern Hemisphere, sea-level was ~25 m higher than today and a strong thermohaline circulation was operating. But the global cooling trend leading to the onset of Northern Hemisphere glaciation had already started in the late Early Pliocene, and the first evidence of intense cooling in the Pliocene is observed at around 3.30 Ma in Marine Isotope Stage (MIS) M2. Earth's climate evolved towards Quaternary-type conditions with well-expressed glacials and interglacials, starting around 2.75 Ma.

The Plio–Pleistocene dinoflagellate cyst record has been studied from DSDP Site 610A and IODP Site 1308 in the eastern North Atlantic. The assemblages reflect the changing climatic/oceanographic conditions in the eastern North Atlantic, and monitor the reorganisation of the sea surface waters at the onset of NHG. The presence of thermophilic species supports an active North Atlantic Current during the warm Pliocene. But, in combination with other proxies, dinoflagellate cysts record rapid and short disturbances of this system during this period at MIS M2 (*c*. 3.30 Ma). The main dinoflagellate cyst assemblage overturn occurs in the late Piacenzian–Early Gelasian, associated with the onset of the Northern Hemisphere glaciation. As a consequence, the palynological assemblage (dinoflagellate cysts and acritarchs) is characterised by numerous extinction events, followed by lower diversity and higher concentrations. In the Gelasian, *Habibacysta tectata* – commonly regarded as a cold-water dinoflagellate cyst – becomes the dominant species. This is a response to reduced influence of the North Atlantic Current on the eastern North Atlantic region. This also supports the observations of a weaker thermohaline circulation, reduction of production of North Atlantic Deep Water and a southward displacement of the polar front.

Recent proposals to lower the basal Quaternary boundary from 1.8 Ma to 2.6 Ma are justified by the dinoflagellate cyst evidence: the major overturn at around 2.6 Ma is the most obvious one in the last 5 Million years.

Stratigraphic utility of new dinoflagellate cysts and acritarchs from the Pliocene and Pleistocene of the eastern North Atlantic

Stijn De Schepper and Martin J. Head

A palynological study of Pliocene and Pleistocene deposits from DSDP Hole 610A in the eastern North Atlantic has resulted in the formal description of several organic-walled dinoflagellate cyst and acritarch taxa (De Schepper and Head, 2008). Among the dinoflagellate cysts, *Impagidinium cantabrigiense* first appeared in the latest Pliocene, within an interval characterised by a paucity of newly appearing species. *Operculodinium*? *eirikianum* var. *crebrum* is mostly restricted to a narrow interval near the Mammoth Subchron within the Pliocene (Piacenzian Stage) and may be a morphological adaptation to the changing climate at that time. An unusual morphotype of *Melitasphaeridium choanophorum* (Deflandre and Cookson, 1955) Harland & Hill, 1979 characterised by a perforated

cyst wall is also documented. In addition, the stratigraphic utility of small acritarchs in the late Cenozoic of the northern North Atlantic region is emphasised. For example, *Cymatiosphaera latisepta* has a known range of Piacenzian–lower Gelasian, and *Lavradosphaera crista* and *Lavradosphaera lucifer* range from Upper Miocene to Piacenzian.

Reference:
De Schepper, S. and M.J. Head, 2008. New dinoflagellate cyst and acritarch taxa from the Pliocene and Pleistocene of the eastern North Atlantic (DSDP Site 610). Journal of Systematic Palaeontology 6(1), 101–117 (doi: 10.1017/S1477201907002167).

Rapid changes in North Atlantic Current behavior during the warm Middle Pliocene

Stijn De Schepper, Martin J. Head and Jeroen Groeneveld

Dinoflagellate cyst assemblages have been compared to independent proxies for sea surface temperature and salinity based on $d^{18}O$ and Mg/Ca ratios of the planktonic foraminifer *Globigerina bulloides* for the Pliocene glacial–interglacial cycle spanning Marine Isotope Stage (MIS) M2 (ca. 3.30 Ma), which represents the first episode of intense cooling in the Pliocene. A same-sample dinoflagellate cyst and geochemical study has documented changes in surface water masses across this interval from DSDP Hole 610A (53˚13.297'N, 18˚53.213'W), at the SW edge of the Rockall Trough in the subpolar environment of the eastern North Atlantic. This location is favourable to monitor changes in the pathway and/or intensity of the North Atlantic Current.

Measurements of $\delta^{18}O$ and Mg/Ca on the planktonic foraminifera *Globigerina bulloides* suggest a temperature variation of *c*. 4˚C between MIS M2 and its bounding interglacials, with MIS M2 similar in temperature to today. The dinoflagellate cyst assemblages are dominated by *Bitectatodinium tepikiense* and other cool-water species during MIS M2, and by *Operculodinium centrocarpum* sensu Wall and Dale during the interglacials. The overturn is relatively rapid (less than 4–6 kyrs), signalling an abrupt disturbance of the North Atlantic Current. Evidence from dinoflagellate cysts, geochemistry and ice-rafted debris points to a freshening of the sea-surface by meltwater towards the end of MIS M2. Thereafter, a vigorous NAC was re-established, although temperatures rose slowly into the subsequent interglacial and did not reach pre-MIS M2 levels until 19,000 years after the end of the glacial.

In summary, our methods demonstrate the potential for tracing NAC variability in the Pliocene eastern North Atlantic. The reconstructions show that the NAC switched rapidly from a glacial to interglacial mode and that North Atlantic thermohaline circulation was sensitive to feedback mechanisms, even during the globally warmer and more equitable conditions of the mid-Pliocene.

Dinocyst assemblages in surface sediment of the North Atlantic, Arctic and North Pacific Oceans, and the use of regional vs. hemispheric databases for quantitative reconstruction of sea-surface conditions

Anne de Vernal and Taoufik Radi

With the enlargement of reference modern databases, the definition of the geographical area to be used for statistical treatments and application of transfer function is a critical issue. The assessment of the relationships between environmental parameters and the distribution of taxa in assemblages can be made using multivariate technique such as canonical correspondence analyses (CCA). However, CCA as other multivariate techniques gives different results depending upon the geographical area selected. For example, in the northeast Pacific, the most determinant parameter identified from CCA is productivity, whereas sea-ice is more important when adding the Bering Sea. As another example, salinity appears determinant in the North Atlantic, but secondary when the hemispheric database is considered. Results obtained on regional subsets of a standardized dinocyst database including 1171 sites from the North Pacific, North Atlantic and Arctic oceans (Figure 1) demonstrate that dinocysts are responding to a combination of parameters, which are weighted differently depending upon the regional hydrography. Therefore, any transfer function approach using calibration (for example, the artificial neural network, the weighted averaging partial least squares, the Imbrie and Kipp technique) should be used with caution, and only when the calibration dataset adequately accounts for changes in the assemblages and the environmental parameters to be reconstructed. By using approaches based on similarity, such as the modern analogue technique (MAT), the problem is not as acute since there is no calibration or assumption of quantitative relationships between assemblages and a given parameter. MAT supposes that a given assemblage of taxa in the fossil record is most likely to have occurred under a combination of environmental conditions characterizing similar modern assemblages of taxa. Inasmuch as close modern analogues can be identified, reconstruction by interpolation can be

made. Therefore, the number of reference sites is critical and the accuracy/reliability of reconstruction should be improved by higher diversity of assemblages representing the largest possible combination of environmental variables.

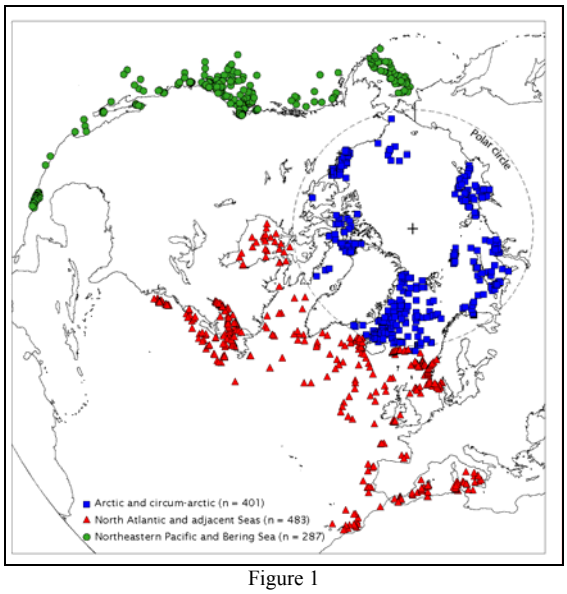


Figure 1

Theoretically, the enlargement of the reference database from regional to hemispheric scales should thus favour better paleoceanographical reconstructions. Validation tests indicate comparable performance for the reconstruction of salinity, temperature and sea-ice cover using regional or hemispheric data sets. In general, the root mean square error (i.e., the standard deviation of the residual between the observed and estimated values) is similar to the standard deviation of the observed values. Two examples of reconstruction have been worked out using regional vs. hemispheric dinocyst databases. The first example is from a 25 000-years sequence of the northwest North Atlantic (HU91-045-094). At this site, the use of North-Atlantic- Arctic or hemispheric databases yield almost identical results and most analogues are found in the Arctic-Atlantic basin. The second example is from a 23 000-years sequence in the Gulf of Alaska (PAR-87A10), northeast North Pacific. In this case, the use of Pacific or Hemispheric databases yields very distinct reconstructions, especially for the glacial stage characterized by assemblages having their modern analogues in the Arctic and North Atlantic (Figure 2).

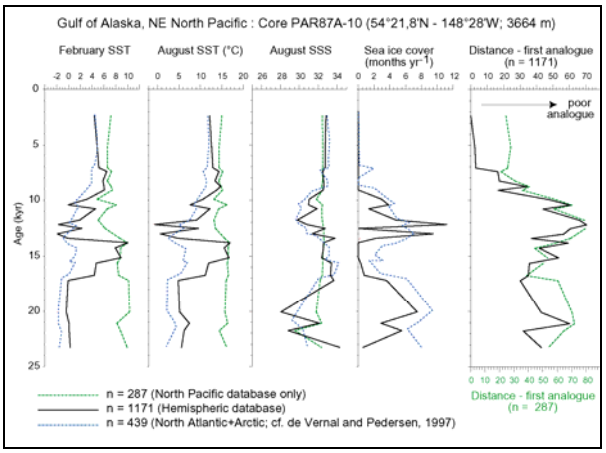


Figure 2

Long-term survival of dinoflagellate cysts in anoxic marine sediments

Marianne Ellegaard, Nina Lundholm, Sofia Ribeiro, Flemming Ekelund and Thorbjørn Joest Andersen

Germination results of individually isolated dinoflagellate cysts from dated sediment cores obtained in Koljö Fjord on the west coast of Sweden will be presented. More than 500 cysts were isolated, mainly of the species *Lingulodinium polyedrum, Pentapharsodinium dalei* and *Scrippsiella trochoidea*. The time-span studied covers approximately the last 100 years. Other species with intact cell contents were also present in the sediment cores but were not as viable down in the core as *L. polyedrum, P. dalei* and *S. trochoidea*. Results will be presented on changes in viability of the three species down-core as well as effects of storage and isolation conditions on germination success and DNA preservation. Quantitative data on densities of viable dinoflagellates and diatoms in the historical sediment layers will be discussed.

Impact of environmental parameters and anthropogenic activities on marine dinoflagellates and benthic foraminifera in the Mediterranean Sea

Rehab Elshanawany

The organic-walled dinoflagellate cysts in surface sediments from different regions of the eastern and western Mediterranean Sea will be investigated in order to obtain an overview about the different species that occur in the Mediterranean Sea and the main ecological gradients that underlay the cyst distribution in the sediment. Moreover, these cysts will be used as bioindicator or proxy to pollution monitoring. Apart from dinoflagellate cysts, we aim to establish correlations between foraminiferal assemblages and environmental factors.

Benthic foraminifera will be also used as bioindicators of environments especially in a heavily polluted area such as Abu-Qir Bay in Alexandria.

A new bloom of *lingulodinium polyhedrum* (stein) Dodge, in Moroccan Atlantic waters

Btissam Ennaffah, Touria Hssaida and Abdelghani Chafik

A major bloom of *Lingulodinium polyhedrum* (Stein) Dodge, was observed on July 2005 in the Moroccan Atlantic coast at walidia lagoon (32°51', 396N-08°53', 455W, 32°47', 944N-08°57', 321W),.Water discoloration was detected from 04 to 07 July 2005, covering an extensive area of this lagoon, including several beach. The dominant taxon was *Lingulodinium polyhedrum*, observed with a high density: 1.4 10^5 $C.L^{-1}$ at station 1 and 7.7 10^5 $C.L^{-1}$ at site2. The maximum was reported at station 3 (10^6 $C.L^{-1}$). During blooming, water temperature was 18-23°C and salinity was about 18-22 PSU. Other dinoflagellate species bloom forming was present during this massive proliferation of *Lingulodinium polyhedrum*, we identify *scripsiella trochoidea* and *Prorocentrum micans* with a respectively density 6,1 10^3 $C.L^{-1}$ and 7,1 10^2 $C.L^{-1}$.

The phycotoxins test showed any toxicity in farms of oyster, present in this lagoon, but mussels was contaminated by DSP during this outbreak; we suspected the implication of these toxic events in the contamination of shellfish areas, and the toxicity of *lingulodinium polyhedrum* need to be considered in the national program of HAB monitoring.

Biodiversity of planktonic dinoflagellates from coasts of the tropical central Mexican Pacific (2001-2005)

Karina Esqueda-Lara and David U. Hernández Becerril.

Dinoflagellates are an important group of the marine phytoplankton all over the world, in terms of diversity, biomass and ecological role. In the tropical Mexican Pacific studies devoted to this group are scarce, hence the justification to recognize its composition and its geographical and temporal distribution. This study attempts to characterize the composition of the species (varieties and forms) of marine planktonic net dinoflagellates from the central zone of the tropical Mexican Pacific, and is based on LM, although some species were also studied by SEM. A total of 112 samples from costs of Isabel Island (Nayarit), Jalisco and Colima, was studied, from which 215 species were identified. 144 species, varieties and forms were illustrated and described, including three new records: *Amphidoma nucula*, *Ceratium bigelowii* and *Dinophysis expulsum*. Some species known to produce toxins or being harmful were also found: *Alexandrium tamiyavanichi*, *Dinophysis caudata*, *D. fortii*, *D. mitra*, *Gymnodinium catenatum*, *Lingulodinium polyedra*, *Noctiluca scintillans*, *Ostreopsis siamensis* and *Protoperidinium crassipes*. The best represented dinoflagellates genera were thecate forms: *Ceratium*, *Protoperidinium*, *Dinophysis* and *Gonyaulax*. Most species are of tropical origin (60%), but also subtropical (3.7), temperate (6.5%), and cosmopolite (10.3%). Perspectives for near future studies on dinoflagellates in Mexico include the fraction of athecate (naked) dinoflagellates, species of benthic and epiphytic habits and molecular taxonomy and phylogeny, which could aid in the knowledge of the biodiversity of this group.

Towards a revised sequencing of the Heinrich event 1 around the British Isles

Frédérique Eynaud, Sébastien Zaragosi, Aurélie Penaud, Samuel Toucanne, Jean-Louis Turon, Jean-Francois Bourillet and Jens Matthiessen

We have compiled multi-proxy data obtained on four cores retrieved from the southern and northern margins of the British Isles: the cores MD95-2002, MD03-2692 from the northern Bay of Biscay and the cores MD95-2009, MD95-2010 from the southern Norwegian Sea (Figure 1).

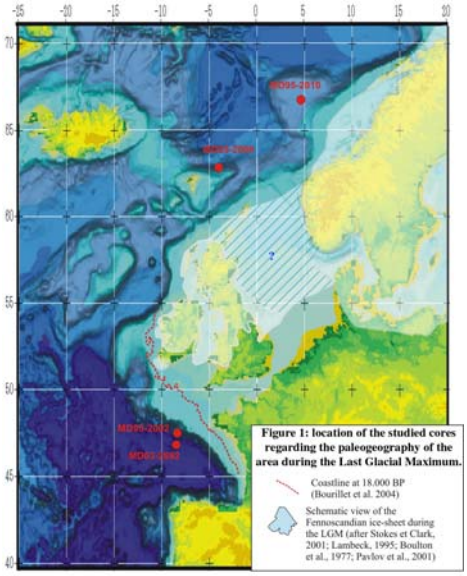


Figure 1

This compilation focuses on the period which covers the Last Glacial Maximum (LGM) and the Heinrich event 1 (HE1), between 22 and 15 CAL-ka BP. Robust age models have been developed for the four sequences (Kissel et al., 1999; Grousset et al., 2000; Zaragosi et al., 2001; Eynaud et al., 2002), allowing us to discuss the precise timing of the events between the different oceanic basins.

The comparison of the palynomorph records reveals the occurrence of distinct events of freshwater release in the oceanic domains that surround the British Isles. These events seem to relay in time and space at the onset of HE1. Actually, our data evidence a preferential area of freshwater discharges located north of the British Isles during the LGM, whereas freshwaters seem to invade the northern Bay of Biscay synchronously at the beginning of HE1.

This observation could be of major importance considering the key location of the British Isles versus the Atlantic Meridional Overturning Circulation (AMOC). Actually, the sequencing of the pan-Atlantic events which have led to the collapse of the northern hemisphere ice-sheets is still controversially discussed, maintaining therefore major questions regarding forcing mechanisms. We use the multiproxy dataset we have compiled to precisely document changes of sea-surface conditions, and tentatively discuss their relation in the frame of the paleohydrological changes that have affected the whole North Atlantic Ocean at that time.

Lower Pliocene dinoflagellate cysts from the Rossello Composite Section, and their statistical analyses

Sarah A. Farquhar and Martin J. Head

Dinoflagellate cysts have been recorded and statistically analysed from the entire Lower Pliocene (Trubi Formation) of the famous Rossello Composite Section in southern Sicily. The lower part of this composite section contains the global stratotype for the Zanclean Stage. The cyclical carbonate deposits of the Rossello Composite Section have already been orbitally tuned, and the dinoflagellate cyst records are placed within this context. The variations within seven discrete sedimentary cycles, representing a cross-section of both the sequence and the major categories of cycles within it, are documented.

The dinoflagellate cyst record exhibits relatively low taxonomic diversity (mean richness of taxa = 19) with a notable absence of protoperidinioid cysts throughout the lower Pliocene. Multivariate statistical analyses show no single strong environmental forcing mechanism on the dinoflagellate cyst assemblages. The most notable feature is the influence of precession on the neritic watermasses.

Previous work and the cyclical nature of the Trubi Formation make the Rossello Composite Section a good candidate for time-series analysis. Both traditional Fourier- and wavelet analyses are applied to the dinoflagellate cyst data, along with other available parameters from the sequence. Wavelet analysis methods are shown to provide an improvement on the Fourier techniques for the analysis of data, especially where there are transient shifts in the periodicities of responses to the forcing patterns. It is found that the strength of cyclicity varies significantly through the succession.

Results also reveal a long-term shallowing of the basin, punctuated by shorter-term shifts in sea-level. During the early Zanclean, the dinoflagellate cyst assemblages were related to changes in the marine isotope record, reflecting fluctuations in shore-line proximity. In the late Zanclean, the dinoflagellate cyst assemblages were more influenced by the temperature component of the marine isotope curve.

Is there a functional nuclear endosimbiont in *Kryptoperidinium foliaceum*?: A life and cell cycle approach

Rosa Isabel Figueroa, Isabel Bravo, Santiago Fraga, Esther Garcés and Gisela Llavería

Kryptoperidinium foliaceum is a binucleate dinoflagellate that contains an endosymbiont chloroplast and nucleus of diatom origin, being unknown whether the endosymbiont nucleus is functional, or it is relict, in process of being eliminated. Life cycle studies following asexual and sexual processes showed that there is a sexual cycle in the host and that the binucleate condition is permanent in the studied strains, since both nuclei undergo division and fusion coordinately. Asexual division was studied by LM and flow cytometry, being shown that the S phase in the endosimbiont nucleus starts 6-8 hours late to that of the host. However, mitosis of the endosymbiont was not observed. Sexuality in the host was confirmed by LM and SEM due to the presence of fusing gamete pairs and planozygotes in clonal cultures (homothallism).

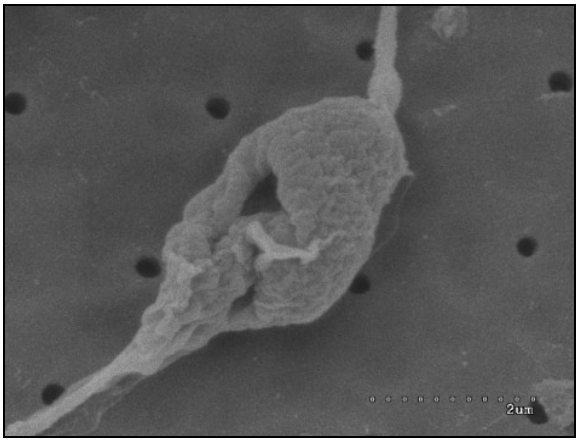
The endosymbiont nucleus might fuse first, since fusing gamete pairs were found to have two dinoflagellate nuclei and one endosymbiontic nucleus. However, planozygotes had apparently normal endosymbiont and dinoflagellate nuclei. Sexual and asexual cysts were formed in culture, wild

and culture cysts having no dormancy period before germination. Our results suggest that the endosymbiont nucleus may be in an early stage of being evolutionary lost, since mitosis and meiosis may be not undergone.

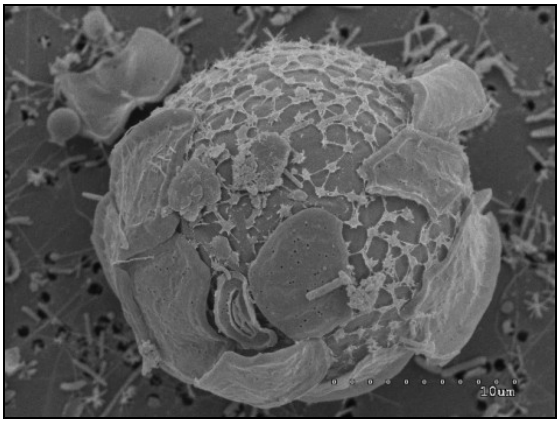
A new species of *Parvilucifera parasite* (*P. sineare* sp. nova): description, host-specificity and interaction with cyst formation in the host dinoflagellate *Alexandrium minutum*

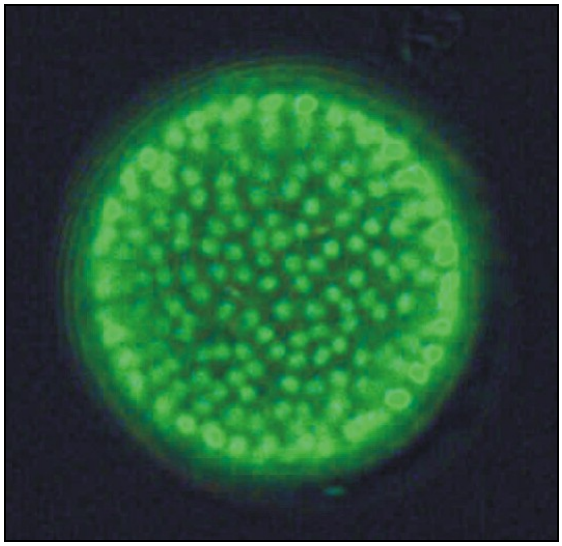
Rosa Isabel Figueroa, Esther Garcés, Ramón Massana and Jordi Camp

A new species of parasite, *Parvilucifera sinerae* sp. nov., isolated from a bloom of the toxic dinoflagellate *Alexandrium minutum* in the harbor of Arenys de Mar (Mediterranean Sea, Spain), is described. This species is morphologically, behaviourally, and genetically (18S sequence) different from *Parvilucifera infectans*, until now the only species of the genus *Parvilucifera* to be genetically analyzed. Sequence analysis of the 18S ribosomal DNA supported *P. sinerae* as a new species placed within the Perkinsozoa and close to *P. infectans*.



Data on the seasonal occurrence of *P. sinerae*, its infective rates in laboratory cultures, and intra-species strain-specific resistance are presented. Life-cycle studies in field samples showed that the dinoflagellate resting zygote (resting cyst) was resistant to infection, but the mobile zygote (planozygote) or pellicle stage (temporary cyst) became infected. Our study of the reproductive behaviour of dinoflagellates confronted with parasitic attack clearly showed that, while sexual recombination increases when the risk of parasitic infection is high, the majority of the population continues to reproduce asexually. Our findings on this newly described parasite point to a complex host-parasite interaction and provide valuable information that leads to a reconsideration of the biological strategy to control dinoflagellate blooms by means of intentional parasitic infections.





Late Pliocene dinoflagellate cysts from the Chillesford Church Pit, Suffolk, Eastern England

Eva Fischer and Martin J. Head

The Norwich Crag Formation, deposited on the southwestern margin of the southern North Sea during the Gelasian Stage (Late Pliocene), is one of three shallow-marine clastic Pliocene formations occurring in eastern England. The Chillesford Sand Member of the Norwich Crag Formation is largely represented by a widespread sheet of fine- to medium-grained well-sorted sand, with sedimentary structures consistent with deposition on a tidal flat. Typically, the deposits are largely devoid of megafossils, possibly indicative of rapid deposition.

The well-known Chillesford Church Pit (TM 38285230) is somewhat atypical in that the sands are shelly in places, poorly sorted, and silty. Earlier studies of this site have reported the molluscs *Mytilus edulis* and *Mya truncata* in growth position; and benthic foraminiferal assemblages are indicative of lagoonal or tidal flat conditions. Pollen from the upper part of the section reflect a temperate forest flora, and a Bramertonian pollen stage has been assigned. The Bramertonian and Antian pollen stages of eastern England have been related to different parts of the same climate cycle, and correlated to the Tiglian C3 pollen substage of the Netherlands, which equates to an interval near the base of the Olduvai Subchron. However, correlations of some of the Late Pliocene deposits of eastern England to those of the Netherlands and the southern North Sea have recently been questioned. In order to cast more light on the age and depositional environment of the Chillesford Sand Member, a detailed study of the dinoflagellate cysts and marine acritarchs based on 17 samples has been undertaken. A relatively low-diversity flora has been recorded, including *Achomosphaera andalousiensis* subsp. *andalousiensis*, Algal cyst type 1 of Head, 1996, *Amiculosphaera umbraculum*, *Bitectatodinium tepikiense*, *Capisocysta lata*, *Habibacysta tectata*, *Impagidinium multiplexum*, *Nannobarbophora walldalei*, *Operculodinium centrocarpum* sensu Wall & Dale 1966, *Operculodinium israelianum*, *Spiniferites falcipedius*, *Spiniferites/Achomosphaera* spp., and *Tuberculodinium vancampoae*. Of these, *Habibacysta tectata*, *Operculodinium centrocarpum* sensu Wall & Dale 1966, *Operculodinium israelianum* and *Spiniferites/Achomosphaera* spp. are common, but the dominance of a particular species varies depending upon the sample. Protoperidiniacean cysts are notably absent, presumably owing to non-preservation. The assemblages support the interpretation of a restricted marine environment during a cool to mild climate, and provide constraints on the age and correlation of the deposits.

Role of dinoflagellate life-cycle in population ecology

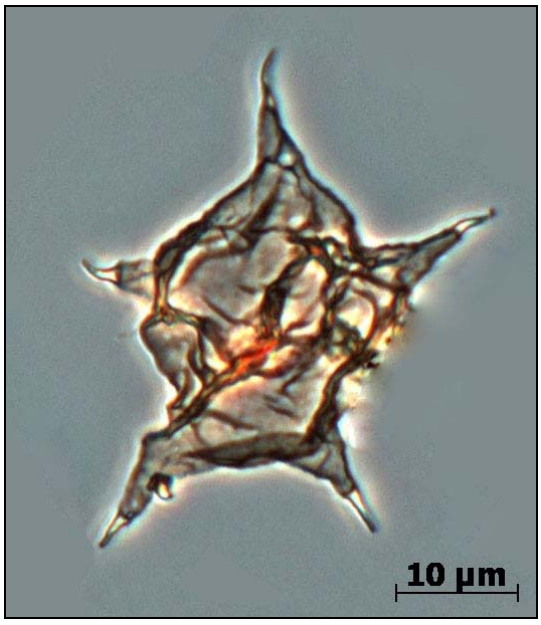
Esther Garcés

Most dinoflagellate species display complex life cycles that include a variety of morphologically and physiologically stages. Many dinoflagellate species alternate between motile planktonic stages and non-motile resting stages (vegetative cells, ecdysal asexual cysts, resting cysts) and the different life stages interact with the environment in quite different ways. Indeed, in many species, planktonic stages are only an ephemeral phase of the organism life cycle and resting stages could represent the majority of the organism's existence. Shifts between different life history stages and their relationships with the physical, chemical and biological environment are very important elements for the species survival, persistence, spreading and in the occurrence and dynamics of blooms so the factors controlling transitions between phases will be deeply revised. Moreover, sexual events in the course of life cycles are at the base of the genetic structure and diversity of populations. Although, there are some advantages for the sexual reproduction, for e.g. elimination of deleterious mutations, sex is an unresolved issue in evolutionary biology given the cost of it. Since the survival and spreading of the populations are affected by the genetic variation, special focus will be paid in the sexual phases of dinoflagellates.

A possible new species of protoperidinioid dinoflagellate cyst from the Oligocene-Miocene transition, Carmen Formation, Northern Colombia

Sandra Lucia Garzon-beltran

A possible new species of protoperidinioid dinoflagellate cyst was encountered in the Oligocene-Miocene transition in Northern Colombia. The cysts are small, acavate, dorso-ventrally compressed and bear five strongly developed horns; a single apical, two lateral and two antapical.



The paratabulation is indicated only by the intercalary archeopyle, which is not always discernible. The possible new species resembles those from the genus *Stelladinium.* Cysts from this genus have, so far, only been encountered in Quaternary sediments. The cysts recorded here were found in a narrow stratigraphic interval from the Carmen Formation, spanning the uppermost Oligocene (P22) to the lowermost Miocene (N4) according to foraminifera biostratigraphy. Our record might constitute the oldest appearance of the genus *Stelladinium*.

Recent changes of bottom water oxygenation and temperature in the Gulf of St. Lawrence: micropaleontological and geochemical evidences

Linda Genovesi, Benoît Thibodeau, Anne de Vernal and Claude Hillaire-Marcel

The deep waters of the Lower St. Lawrence Estuary (LSLE) and Gulf show a recent decrease in dissolved oxygen concentrations, which may be due to eutrophication and/or to a warming of incoming waters. In order to reconstruct variations in pelagic productivity and benthic conditions at centennial scale, we analyzed the micropaleontological and geochemical content of a sediment core (COR37BC) collected in the Laurentian trough of the Gulf of St. Lawrence (GSL), which represents approximately 300 years of sedimentation.

In this core, the dinocyst assemblages are dominated by *Pentapharsodinium dalei*, *Islandinium minutum*, *Nematosphaeropsis labyrinthus*, *Operculodinuim centrocarpum* and *Brigantedinium* spp. The assemblages do not show much variations, except for the surface sample (0-1 cm), in which we note an important decrease in the abundance of heterotrophic taxa *Islandinium minutum* and *Brigantedinium* spp. Dinocyst concentrations range from ~33 627 to ~91 138 cysts/g, which permit to evaluate fluxes averaging around 2865 cysts/m2/yr. No major changes in fluxes are observed, suggesting uniform pelagic production throughout the entire core. Moreover, the application of the modern analogue technique permitted to reconstruct relatively constant primary productivity of about 283 $gC/m^2/yr$ with the MODIS database or 182 $gC/m^2/yr$ with de dataset of Antoine et al (1996) (for the method, see Radi and de Vernal: Marine Micropaleontology, in press). This is consistent with geochemical (organic C, C/N) and isotopic (δ^{13}Corg, δ^{15}N) data obtained from the analysis of organic matter in the sediment, which also suggest uniform organic fluxes during the last centuries. Although no changes in productivity can be detected, the reconstruction of sea-surface conditions suggests two cooling pulses during the 20th century, whereas the surface sediments record a recent warming in winter.

The palynological results indicate hydrographical variations, but there is no evidence of eutrophication in the GSL as it was hypothesized for the LSLE. In complement to palynological data, benthic foraminifer assemblages were analysed together with the composition of their shells in order to identify changes in bottom waters. The decrease in abundance of *Nonionellina labradorica* concomitant with the increase of *Oridorsalis umbonatus* suggest warming of the bottom waters. The decrease of $\delta^{18}O$ in the shells of *Bulimina exilis* indicates an increase of temperature of at least 1.5ºC during the past decades. Moreover, the occurrence of *Brizalina subaenariensis* and *Cassidulina laevigata* in the upper 10 cm of the core mark the recent decrease in dissolved oxygen concentrations. These results show that the recent oxygen depletion of bottom waters in the GSL is not related to an increase in primary productivity, but rather seems to be the consequence of a warming in the bottom water layer which represents a mix of North Atlantic intermediate water and Labrador Current water. An enhanced relative contribution of the North Atlantic intermediate water and/or recent warming of sub-surface waters in the Labrador Sea and North Atlantic can be invoked.

No Invasive Species On Board ─ The effect of the biocide PERACLEAN® Ocean on dinoflagellate cysts

Dominique Hamel, Nathalie Simard, Simon Cartier, André Rochon and Suzanne Roy

The discharge of ship's ballast water is recognized as a leading mechanism for the introduction of nonindigenous aquatic species throughout the world. The research program *No Invasive Species On Board* (NISOB) aims to determine the efficiency of the biocide PERACLEAN® Ocean (formulated by Evonik Industries-Degussa) to kill all living organisms present in ballast waters. Among these organisms, dinoflagellates are key species since their resting cysts found in bottom sediments can be taken up during the filling of ballast tanks and can generally survive in dark and low oxygen conditions. At destination ports, viable specimens can then be discharged with ballast water, contributing to the spreading of several harmful species. Because of their high resistance, these cysts constitute an ultimate test for any ballast water treatment. The biocide

PERACLEAN® Ocean was first tested on cysts included in a sediment matrix under different laboratory conditions representative of seawater-filled ballast tanks. The biocide was also tested under operational conditions during three voyages aboard a commercial ship in the fall of 2007.

Because many cysts of the harmful species *Scrippsiella trochoidea* and of the toxic algae *Alexandrium tamarense* experienced spontaneous germination in laboratory experiments after a few days of treatment with the biocide at concentrations as high as 400 and 600 ppm, we conclude that the PERACLEAN® Ocean concentrations tested did not efficiently inactivate dinoflagellate cysts under the conditions used in our experiments. Our results contrast with previous studies that have demonstrated its efficiency to kill almost all aquatic and marine organisms. The composition and/or the amount of sediment that comes in contact with the biocide seemed to affect its efficiency. The tests conducted aboard the ship Jaeger Arrow using 200 ppm PERACLEAN® Ocean yielded similar results since the percentage of viability of the cysts collected in the tanks at the beginning and at the end of each three voyages were almost similar in the control (47 to 76% of cyst viability) and the treated tanks (44 to 74% of cyst viability). The quantity of sediment already present at the bottom of the tanks prior to the sea trial was likely too important (thickness of 0,5 to 1cm) to be efficiently treated by the biocide formulated to treat the ballast water during the uptake.

Fjords, climate change and dinoflagellates

Rex Harland

The association between fjords and dinoflagellate research dates back to, at least, the late 19th C when Aurivillius (1898) documented plankton from the Skagerrak, and several fjords on the west coast of Sweden. However the association between the fjord environment and the cysts of dinoflagellate may not have originated before 1945 when Braarud described the cyst formation of the species *Goniaulax tamarensis* and *Protoceratium reticulatum* in cultures originating from Oslofjord, and Nordli (1951) described the cysts of *Goniaulax polyedra* from the same source. Gunnar Erdtman (1954) published an important account of living dinoflagellate cysts produced within the local phytoplankton of Gullmarfjord, Sweden and in 1976 Barrie Dale provided a seminal paper on the dinoflagellate cysts in Trondheimsfjord, Norway linking them to known plankton records.

This relationship is especially important to the ecology of dinoflagellate cysts as fjords, especially sill fjords, provide an environment of deposition that resembles more of a closed system than any found in the shelf seas or in the open ocean. The fact that many of the fjords are developed on Palaeozoic or older bedrock virtually eliminates problems of reworking, and the development of anaerobic or hypoxic bottom conditions, because of the lack of water movement within the fjord and minimal bioturbation, contributes to the preservation of all cyst types whether susceptible to oxidation or not. Fjords act as large natural traps preserving sediment deposited over considerable lengths of time without disruption; indeed sedimentation rates are often sufficiently high to enable ultra high resolution sampling close to an annual frequency. Indeed they are natural laboratories for high spatial and temporal resolution studies.

Recently I have been involved in research on the dinoflagellate cyst analysis of fjord sediments from the west coast of Sweden, with Kjell Nordberg, which has involved high resolution sediment sequences and the detailed examination of the last couple of centuries. Ongoing research on similar material is focussing on the last two and a half millennia including the Roman (100-200 BC), Medieval (900-1250 AD), and Modern (1970-1990 AD) warm periods together with the Little Ice Age (1350-1800 AD) with a view to documenting changes within the dinoflagellate cyst assemblages as the climate moves from warmer to cooler periods and back again through the latest part of the Holocene. Also I am involved in the analysis of sediment trap material from the Svalbard archipelago, with John Howe, as recent hydrographical change introduces North Atlantic water into Arctic environments. Revelations and difficulties abound but do nothing to detract from the fascinating study of dinoflagellates and their cysts. In particular the use of ever more detailed analyses and the change in scale this involves, in an effort to both document and explain climate change within the recent past, reveals new difficulties that require understanding. This is especially so if problems of marine pollution, eutrophication, acidification and global warming are to be confronted. The challenges ahead include the separation, with confidence, of ongoing natural variation from cultural factors and the better understanding of the ecology of dinoflagellate and their cysts and how this information can be utilised in our interpretation of the fossil record.

Investigations of calcareous dinoflagellate cysts for surface water property changes in the Miocene Atlantic Ocean

Sonja Heinrich

The middle- and upper Miocene is characterised by major climatic shifts to colder global temperatures. These periods of cooling (Mi-Events) were characterized by oxygen isotopic shifts that have been related to size changes of the Antarctic ice-sheet as well as the cooling of ocean currents. These conditions had a strong influence on ocean circulation, nutrient contents and, therefore, on the productivity of the oceans. The complex interaction is far from being fully understood. To understand paleoceanographic changes, it is important to investigate ocean circulation during periods undergoing significant variation. The Namibian region, at the south-western African continental margin off the Orange River mouth, is of major interest because of its extreme high marine productivity related to the coastal upwelling, which had its start and development in the middle- and upper Miocene. Calcareous dinoflagellate cysts are a useful tool for the reconstruction of surface water conditions; and their association is, as primary producers, strongly related to environmental parameters of the water masses of their habitat.

Within this study, detailed paleoceanographic reconstructions will be established based on calcareous dinoflagellate cyst associations as well as on the isotopic and elemental composition of their shells.

Morphological study of three dinoflagellate marine species from the Mexican Pacific in culture conditions

David U. Hernández-Becerril

Cultures of marine microalgae have greatly contributed to the better understanding of the morphology, phylogeny, life cycles, physiology and ecology of the species. Three species of marine dinoflagellates were studied from cultures, originally established from samples of the Mexican Pacific (central and southern parts: Lázaro Cárdenas and Acapulco). All cultures are clonal, not axenic, "semicontinuous", and are kept in media L1 and L1SE (enriched with soil extract), in a light-darkness cycle of 12:12, at two temperatures, 18 and 20° C + 1° C and irradiance of 90.5 µmol m^{-2} s^{-1} and 166.8 µmol m^{-2} s^{-1}, respectively. LM, SEM and TEM (for *Heterocapsa pygmaea*) were used to study the morphology of the species *Heterocapsa pygmaea* (25A and 46A), *Protoceratium reticulatum* (76A) and *Bysmatrum* sp. (42L). The two former species may form blooms and *P. reticulatum* is considered potentially toxic, but both have been poorly-studied in Mexico, whereas the latter is a new species. *H. pygmaea* has minute external scales that aid positive identification. *Bysmatrum* sp. shows predominance of a type of cysts in the cultures, with few thecate forms: its general morphology resembles other *Bysmatrum* species (especially the large apical pore producing mucus), but the tabulation and ornamentation of the theca appears to be different, hence we consider it a new species. The observations indicate that cultures are becoming more important in determining the real biodiversity of this group, including studies of molecular phylogeny.

Study of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm from the tropical Mexican Pacific

David U. Hernández-Becerril

During the course of sampling and studying marine phytoplankton from the Mexican Pacific, various new records have been recognized and even few new species of dinoflagellates have been described. We have found the species *Centrodinium pulchrum* Böhm, a rather large thecate form, in some samples from the tropical Mexican Pacific, which has been studied in certain detail to define its morphological variation and its tabulation. An important variation was found in size and shape. Thecal formula detected is: Po, 3', 3a, 6'', 6c, 5-6s, 5''', 1p, 1''''. Some specimens were found forming short chains (2-3 cells); the associated structures to attach consist in two relatively large pores: one is located in the most anterior left lateral epithecal part, close to the apical pore, whereas the other is in the middle right lateral hypothecal part. *Centrodinium pulchrum* is morphologically very similar and therefore closely related to *C. eminens* Böhm, and possibly to *C. complanatum* (Cleve) Kofoid. However, despite shape variation in *Centrodinium pulchrum*, the anterior epithecal end was consistently wide and truncated, and with a conspicuous but poorly-developed list at the most dorsi-anterior part, and there were no overlap or intergrades with those two species. The genus *Centrodinium* is distributed in tropical and subtropical waters, but it is rather rare. All species of the genus should be revised, as well as the relationship and phylogeny with other presumably related genera such as *Corythodinium*, *Murrayella*, *Oxytoxum* and *Pavillardinium*. A new dinoflagellate

family could be proposed to accommodate the genus, provided the uncertainty on its classification.

Centre of Excellence for Dinophyte Taxonomy (CEDiT) at the German Centre for Marine Biodiversity Research (DZMB) – heard about it yet?

Mona Hoppenrath and Malte Elbraechter

Living dinoflagellates are the focus of diverse research topics. They contribute significantly to the biodiversity of marine ecosystems as primary producers and secondary consumers. Many toxic or harmful flagellates in the plankton are dinoflagellates. The taxonomic knowledge of living dinoflagellates (comprising about 2500 species) is scanty and restricted to few specialists worldwide. Nevertheless, many new dinoflagellate taxa have been described over the last decades. The last worldwide revision of dinoflagellate species was published in 1937. Since then the taxonomic characterization of many species and genera has been changed or emended. Any taxonomic work starts with the original descriptions of the taxa that are often scattered in various European journals from the nineteenth century – not available to many scientists.

The centre will provide a complete check-list of all described living dinoflagellate genera and species with exact bibliographic details online. In addition, we intend to provide all original descriptions electronically. Next to this core databases it is planned to make available information of general interest for the dinoflagellate research community, e.g. important links and images. In the future one main task will be to archive reference material from cultures or field samples of dinoflagellate blooms. The centre was founded in 2005 and is now in the process of development. The active contribution from potential users through discussions, constructive criticism, provisional data and sample material is highly welcome and will hopefully be stimulated by this talk!

Phylogeny and character evolution in dinoflagellates with complex organelles as inferred from SSU and LSU ribosomal gene sequences.

Mona Hoppenrath, T.S. Bachvaroff, S. Handy, C.F. Delwiche and Brian S. Leander

The molecular phylogeny and evolutionary morphology of polykrikoids and warnowiids will be addressed in this poster. Polykrikoids and warnowiids possess several distinctive organelles, such as complex nematocysts. Moreover, all warnowiids possess a complex eye-like organelle called the 'ocelloid', and some species (i.e. *Erythropsidinium*) have also developed a dynamic appendage called the 'piston'. Phylogenetic analyses of small (SSU) and large (LSU) subunit rDNA sequences derived from manually isolated, uncultured cells of *Pheopolykrikos beauchampii*, *Pheopolykrikos hartmanii*, *Polykrikos kofoidii*, *Polykrikos lebourae*, *Polykrikos herdmanae*, *Proterythropsis* sp., *Nematodinium* sp. and *Warnowia* sp. enabled us to test and refine a hypothetical framework built from comparative morphology of these species. A well-supported *Polykrikos* clade formed the nearest sister lineage to *Gymnodinium fuscum*, the type species of the genus. These results demonstrated that pseudocolonies in polykrikoid dinoflagellates evolved at least two times independently, and the best synapomorphy for a *Polykrikos* clade was the presence of nematocyst-taeniocyst-complexes and two nuclei, irrespective of zooid number. Sequences from the three species of warnowiids formed a well-supported clade within the *Gymnodinium* sensu stricto clade (including *Polykrikos*, *Pheopolykrikos* and *G. fuscum*).

Dinoflagellate phylogeny as inferred from heat shock protein 90 (HSP 90) gene sequences

Mona Hoppenrath and Brian S. Leander

At present, the early evolutionary history of dinoflagellates and the relationships between the major subgroups remain largely unresolved. The in-group relationships of dinoflagellates have been analyzed mainly with ribosomal genes, which have proven to be inadequate. Building a robust phylogenetic framework for dinoflagellates will rely on multi-gene analyses on relative comprehensive taxon samples. Increasing the dataset for nucleus encoded heat shock protein 90 (hsp 90) gene sequences in dinoflagellates is expected to contribute to this challenging task. We have more than doubled the existing hsp 90 dataset for dinoflagellates to over 30 sequences. Most of the dinoflagellate orders are now represented in this dataset, with an emphasis on heterotrophic taxa. Phylogenies inferred from hsp 90 were directly compared to phylogenies inferred form ribosomal gene sequences using identical taxon samples. Our results indicate that all athecate taxa branched as a paraphyletic stem group, and *Noctiluca scintillans* did not represent the earliest diverging lineage among them. Moreover, species known to produce very long branches in ribosomal gene analyses, like *Amphidinium carterae* and *Haplozoon*

axiothellae, showed reduced branch lengths, which mimimzed the risk of methodological artifacts.

Ultrastructure and phylogeny of a novel tube-forming, intracellular parasite of dinoflagellates: Parvilucifera prorocentri sp. nov. (Alveolata, Myzozoa)

Mona Hoppenrath and Brian S. Leander

We have characterized the molecular phylogeny, intracellular development and ultrastructure of a novel parasite that infected the marine benthic dinoflagellate *Prorocentrum fukuyoi*. The parasite possessed a combination of features described for perkinsids and syndineans, and also possessed novel characters associated with its parasitic lifecycle. Reniform zoospores, about 4 µm long, possessed a transverse flagellum, alveoli, a refractile body, a mitochondrion with tubular cristae, a syndinean-like nucleus with condensed chromatin, micronemes, two-parted trichocysts with square-shaped profiles (absent in perkinsids) and oblong-shaped microbodies. Like *Parvilucifera*, the zoospores also possessed a shorter posterior flagellum, a heteromorphic pair of central microtubules in the anterior axoneme and a reduced pseudoconoid positioned directly above an orthogonal pair of basal bodies. Early developmental stages consisted of a sporangium about 5-15 µm in dia. that contained spherical bodies and amorphous spaces. The undifferentiated sporangium increased to about 20-25 µm in dia. before being enveloped by a cyst wall with a convoluted mid-layer. The sporangium differentiated into an unordered mass of zoospores that escaped from the cyst through a pronounced germ tube about 4-5 µm in dia. and 10-15 µm long. Weakly developed germ tubes have been described in *Perkinsus* but are absent altogether in *Parvilucifera* and syndineans. Comparison of these data with other myzozoans enabled us to build a hypothetical framework for understanding character evolution during the earliest stages of perkinsid and dinoflagellate evolution.

Dinoflagellate cysts palynostratigraphy of the Middle Jurassic - Lower Cretaceous sequences in the Agadir - Rabat Region, Western Atlantic Margin, Morocco

Touria Hssaida and Fatima Oumalch

The primary focus of this paper is to report recent results of a major biostratigraphic project on the palynological investigation carried out, using dinoflagellate cysts, on cuttings samples, spanning the interval from the Callovian to the Albian, from four petroleum exploration wells, provided by ONHYM. The study is centred in the Rabat – Essaouira - Agadir region (western Morocco), and the organic-walled microfossils yielded, comprise spores, pollen grains, foraminiferal test linings and significant dinoflagellate cysts. The recovered dinocysts assemblages, ranging from Bathonian to Albian, allowed the refining of the ages, inferred by previous micropaleontological studies, on the basis of poor foraminifera assemblages and have been useful in interpreting the paleoenvironments of the Jurassic - Cretaceous sequences tapped by the investigated boreholes. The present work stresses the use of dinoflagellate cysts in age determinations of sedimentary deposits, and the results may have a wider application for the Moroccan Atlantic margin as a whole and could assist in the ongoing offshore exploration activity.

Morphology and phylogeny of a *Cochlodinium*-like unarmored dinoflagellate with reference to its cyst-motile cell relationship

Mitsunori Iwataki, Hisae Kawami, Yoshihito Takano, Stanley Ping-chuen Law, Songhui Lu, Yasuwo Fukuyo and Kazumi Matsuoka

Motile cell and cyst morphology, and the phylogenetic position of an enigmatic unarmored dinoflagellate resembling *Cochlodinium* were investigated using light and scanning electron microscopy and molecular phylogeny based on SSU rDNA sequences. Motile cell has the cingulum encircling the cell about one and a half time and margins of the cingulum extruded outside, making the uneven cell outline. A spherical nucleus located near the center of the cell, trichocysts underlying the cell membrane, and nematocyst-like structures were observed. Chloroplasts roughly reticulated are peripherally located. A loop-shaped apical groove curves slightly left side, similar to that of *Polykrikos*, can be observed under a light and scanning electron microscope. Motile cells usually form a cell chain composed of two cells. Reddish brown cysts ellipsoidal in shape and covered with fin-like structures were observed from different location. Molecular phylogeny based on SSU rDNA sequences revealed that the close relationship between the motile cell and reddish brown cyst. They are closely related to the clade including *Polykrikos* spp. and *Pheopolykrikos hartmannii* in *Gymnodinium* sensu stricto. This implies the character of this species,

having nematocysts and without forming pseudocolony is an ancestral state of the *Polykrikos* group in gymnodinioid dinoflagellates. Cell shape of this species is similar to *Cochlodinium geminatum* (Schütt) Schütt sensu Kofoid and Swezy (1921), however, differs from the original description of *C. geminatum* (Schütt 1895). Morphology of the cyst resembles that reported as *Cochlodinium* sp., which was previously supposed to cyst of *C. polykrikoides*.

The ecological roles of heterotrophic and mixotrophic dinoflagellates in marine food webs

Hae Jin Jeong

Establishing the food webs in the marine planktonic community is one of the most important concerns in understanding the cycling of materials and flows of energy and predicting further responses of marine ecosystems to diverse-scale-environmental changes. For the last four decades, several new ecological concepts in marine planktonic food webs have been established. In particular, dinoflagellates have been one of the triggers for discovering new pathways and in turn establishing new ecological concepts in marine ecosystems. Marine dinoflagellates which are phototrophic or heterotrophic are often abundant and ubiquitous protists in marine environments. For a long time phototrophic dinoflagellates had been thought to be exclusively autotrophic dinoflagellates and thus treated like other phytoplankton such as diatoms and phototrophic nanoflagellates. However, recently many phototrophic dinoflagellate species have been revealed to be mixotrophic organisms. Mixotrophic dinoflagellates are able to feed on diverse prey items including bacteria, picoeukaryotes, nanoflagellates, diatoms, other mixotrophic dinoflagellates, and heterotrophic protists. Thus there are wide predator-prey relationships among mixotrophic dinoflagellates and between mixotrophic dinoflagellates and other plankton and the roles of the mixotrophic dinoflagellates in marine planktonic food webs become very diverse. Heterotrophic dinoflagellates are also able to feed on the kinds of prey species similar to that for mixotrophic dinoflagellates. Thus, heterotrophic and mixotrophic dinoflagellates may sometimes compete for common prey. In turn, heterotrophic and mixotrophic dinoflagellates are also known to be important prey for several planktonic consumers, such as ciliates and copepods. Therefore, to understand the roles of heterotrophic and mixotrophic dinoflagellates in marine planktonic food webs, interactions between heterotrophic or mixotrophic dinoflagellates and prey should be continuously explored. The present presentation reviews predator-prey relationships among mixotrophic dinoflagellates, and between heterotrophic or mixotrophic dinoflagellates and diverse prey or predators. Also, I provide an insight into new paradigms of marine plankton food webs reflecting recent new discoveries related to heterotrophic or mixotrophic dinoflagellates dinoflagellates.

Dinocysts as a proxy for past climatic and redox conditions: a view from the Southern Ocean

Monika Kodrans-Nsiah, Oliver Sachs and Karin Zonneveld

Organic-walled dinoflagellate cysts (dinocysts) are frequently used palaeoproductivity and palaeoclimate proxy. Recently they were also associated with the bottom water oxygen concentrations. In this study, we investigate two short cores (last few hundred years) from Southern Ocean to asses dinocysts reliability as proxy in different sedimentary conditions. The 705 coring site is located at the Antarctic Polar Front (APF) characterised by high productivity and shallow oxygen penetration depth whereas the 703 site lies within the high-chlorophyll low nutrients areas south of the APF and is characterised by high oxygen concentration in pore waters. The dinocyst fluxes in core 705 are generally high although two intervals with decreased fluxes can be distinguished. These intervals coincides with the higher percentages of autotrophic species that are associated with relatively warmer-water masses, and are here interpreted as a result of southward shift of maximum sea-ice limit (MSIL). Dinocyst fluxes recovery is subsequently interpreted as a northern shift of the MSIL. In the younger part of the core our reconstruction is supported by satellite data. The dinocyst fluxes in core 703 are on average much lower. Fluxes of heterotrophic species display sharp decrease within first few cm of the core whereas fluxes of autotrophic species initially increase. Comparison of dinocyst flux and total organic carbon profiles with *in situ* oxygen profile suggest overprinting of productivity signal by the (early) diagenesis. Further relation between dinocyst degradation and exposure time and oxygen concentrations at the time of deposition is investigated.

Stable oxygen isotopes of the phytoplanktic dinoflagellate species *Thoracosphaera heimii* to reconstruct sea-surface temperature of the last 45 ka years off NW Africa

Marion Kohn, Karin A.F. Zonneveld, Karl-Heinz Baumann, Barbara Donner, Helge Meggers and Stefan Steinke

The isotopic composition and elemental chemistry of calcareous microfossils often form the backbone of palaeoceanographic and palaeoclimatic studies.

Recent culture experiments have documented a clear relationship between the oxygen isotope composition of *Thoracosphaera heimii* and temperature. Earlier studies showed that the isotopic composition of the calcite shells of this photosynthetic cyst producing dinoflagellate reflects temperatures of the deeper parts of the photic zone in South Atlantic surface sediments, notably of deep chlorophyll maximum (DCM) depth.

The high potential of the oxygen isotope composition of T. heimii as palaeotemperature proxy is supported by the broad geographic distribution of *T.heimii*, its stable position within the water column, its presence in the geological record since the Late Cretaceous and its resistance against dissolution compared to other plankton groups. These characteristics might result in a reduced sensitivity of this proxy to factors that often complicate the interpretation of the stable isotopic signal of organisms that are hardly used in palaeoceanographic research. The production of their calcareous material might take place in different depths in the water column, can show ontogenic induced variability, they are sensitive to (selective) dissolution or can be geographically determined by seasonal production. Since *T. heimii* forms immotile vegetative cysts and the motile phase last a few minutes to a few hours their vertical movement in the photic zone is rather limited. It seems that they are more robust (against dissolution) than other calcareous dinoflagellates and they are widespread in temperate to tropical regions.

However, until now this proxy has not been tested in a time series analysis. To overcome this problem, we isolated *T. heimii* cysts from sediments of core GeoB 8507 located in the Cape Timiris canyon off the Mauritanian coast using a density/size separation method. We focused on the last 45 ka years, especially the changes between glacial and interglacial intervals. To test and evaluate the new proxy we compared our results with well known proxies such as $\delta^{18}O$ of the planktic foraminifera *Globigerina bulloides* and biomarkers (Uk37) of coccoliths that have been measured on the same samples. Furthermore, we compare our results with TOC and $CaCO_3$ analyses.

We observed quite well the change between interglacial and last glacial. There is a relatively small offset between both species that might be explained by species-specific differences. We speculate that the difference between the offset during glacial and interglacial times might be explained by vital effects.

The marine dinoflagellate *Alexandrium ostenfeldii* in low salinity waters of the northern Baltic Sea: morphological, molecular, toxicological and ecophysiological characterization

Anke Kremp, Tore Lindholm, Nicole Dressler, Katrin Erler, Gunnar Gerdts, Sanna Eirtovaara and Elina Leskinen

In the past years, late summer blooms of the bioluminescent dinoflagellate *Alexandrium ostenfeldii* have become a recurrent phenomenon in coastal waters of the central and northern Baltic Sea. Clonal cultures were established from blooms at the SW coast of Finland for morphological, molecular, toxicological and ecophysiological investigations. The Finnish isolates had the typical morphological features of *A. ostenfeldii* such as large size, a prominent ventral pore and an orthogonally bent first apical plate. Considerable variation of sulcal anterior plate shapes occurred within and among the examined isolates, making unambiguous differentiation from closely related *A. peruvianum* difficult. The Finnish strains were genetically distinct from Northern European, North American and New Zealand isolates of the species, forming a separate clade together with isolates from southern England and an *A. peruvianum* morphotype from the Spanish Mediterranean. Toxin analyses confirmed the presence of the PSP toxins GTX2, GTX3 and STX in both Finnish isolates with GTX3 being the dominant toxin. Total relative PSP toxin contents were moderate, ranging from approximately 6 to 15 fmol per cell at local salinities of 5 and 10 psu respectively. Spirolides were not detected. Salinity tolerance experiments showed that the Finnish isolates were well adapted to the low salinities of the Baltic Sea. With salinity range of approximately 6 to 20-25 psu, Baltic populations are physiologically distinct from their marine relatives.

Impact of sewage discharge on dinoflagellate cyst production in coastal bays of southern Vancouver Island (BC, Canada)

Alanna Krepakevich and Vera Pospelova

Concern about human-induced coastal eutrophication has prompted a search for biological indicators that can be used to assess present and past status of estuarine health. In this work we focus on application of dinoflagellate cysts to estimate the possible impact of the Greater Victoria region of Southern Vancouver Island's current wastewater management practices. Two submerged outfall systems discharge raw sewage, after screening for solids, directly into coastal waters that are located within a complex physical environment. Despite dispersal by strong tidal currents and mixing of high-nutrient oceanic input into the estuarine circulation within Juan de Fuca Strait, the basin topography may allow for localized cultural eutrophication.

This pilot study investigates the impact of effluent by comparing chemical contamination and organic-walled dinoflagellate cyst abundance and diversity from surface sediment samples collected September 2007. Site locations include those directly adjacent to wastewater outfall at Clover and MacCaulay Points, as well as from a variety of near-shore environments with differing tidal flow influences inclusive of Parry, Cadboro and Cordova Bays (BC, Canada).

Excellent dinoflagellate cyst assemblages have been recovered and 30 cyst taxa were identified. Sedimentary cyst concentrations, serving as a proxy of dinoflagellate production, increase by approximately double in samples bordering effluent stations. In general, dinoflagellate cyst assemblages are characterized by relatively high proportion of cysts produced by heterotrophic dinoflagellates (round Protoperidinoids and *Echinidinium* species). The most common autotrophic taxa are *Spiniferites*, *Operculodinium centrocarpum*, cysts of *Pentapharsodinium dalei* and *Alexandrium* types. Cyst abundance, species richness, the proportion of cysts produced by heterotrophic and autotrophic dinoflagellates and the composition of cyst assemblages reflect spatial variation in abiotic factors. Due to the proximity to a large urban centre with a prominent aquatic recreation community, the potential of eutrophication of toxic species is of greatest concern.

Late Holocene paleoceanography of Effingham Inlet, Vancouver Island, Canada, using dinoflagellate cyst assemblages

Arun Kumar, Graeme T. Swindles, R. Timothy Patterson and Helen M. Roe

Effingham Inlet is a 15 km long anoxic fjord, located on the southwest coast of Vancouver Island that opens in the Pacific Ocean through Barkley Sound. This inlet has two sub basins, the inner and the outer, divided by a 45 m deep sill (inner sill) located in the narrow channel. Another 65 m deep sill (outer sill) separates the outer basin from Barkley Sound. Sedimentary deposition within these basins is comprised almost exclusively of annually deposited laminated couplets, with each comprised of a winter deposited terrigenous and spring to fall deposited diatomaceous component. Two piston cores one each from the Outer Basin (TUL 99 B11) and the Inner Basin (TUL 99 B03) were studied for their dinoflagellate cysts.

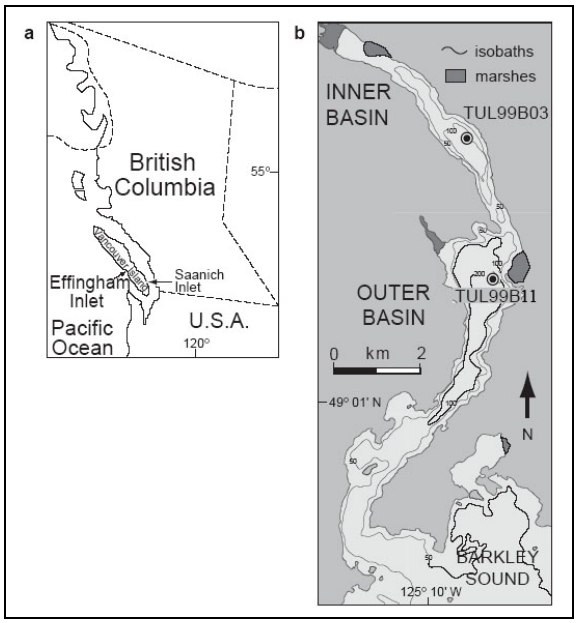


Fig. 1. Geographic location of Effingham Inlet, Vancouver Island showing core sites

The modern distributional dinoflagellate cyst datasets of Radi et al. (2004, 2007), which document the environmental gradients in both estuarine environments and throughout the NE pacific margin, were analyzed utilizing Canonical Correspondence Analysis (CCA). The CCA results showed that temperature, salinity and productivity are important controls on the distribution of taxa in the region. However, many of the environmental variables are highly intercorrelated, leading to a large degree of

redundancy in the environmental dataset. A series of partial CCAs were carried out to examine which variable(s) has a significant independent influence on distribution of taxa (e.g. Telford, 2006). The results showed that the most significant variables are winter temperature explaining 12 % ($p<0.002$) and Productivity explaining 10% ($p<0.002$) of the variance in the data. Transfer functions were developed for winter temperature and productivity using MAT and model performance was improved through the removal of outliers. The transfer functions were applied to the two fossil sequences and sample-specific errors of prediction were estimated by 1000 bootstrap cycles. The reconstructions suggest marked changes in winter temperature and productivity over the last ca. 5000 years.

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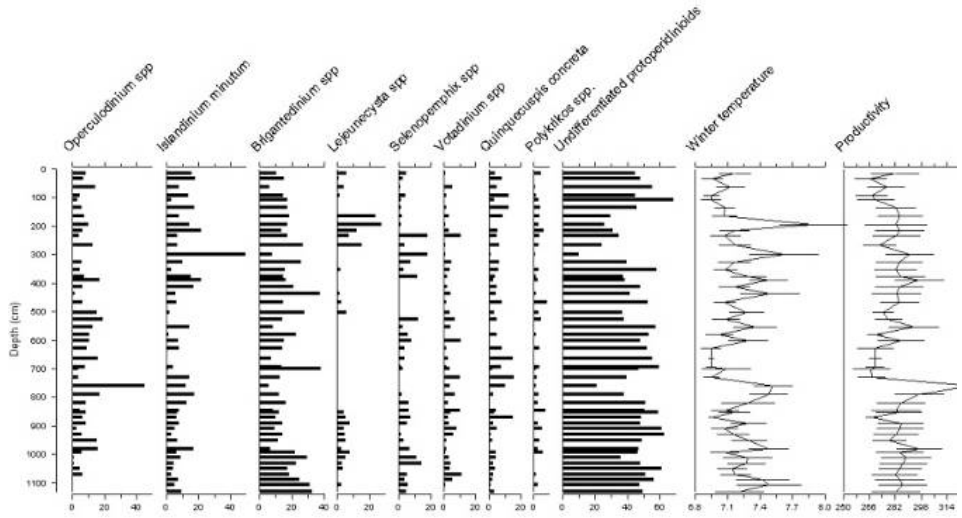


Fig. 2. Distribution of dinoflagellate cysts in Inner Basin core TUL 99 B03 and interpreted winter temperature and productivity through the core

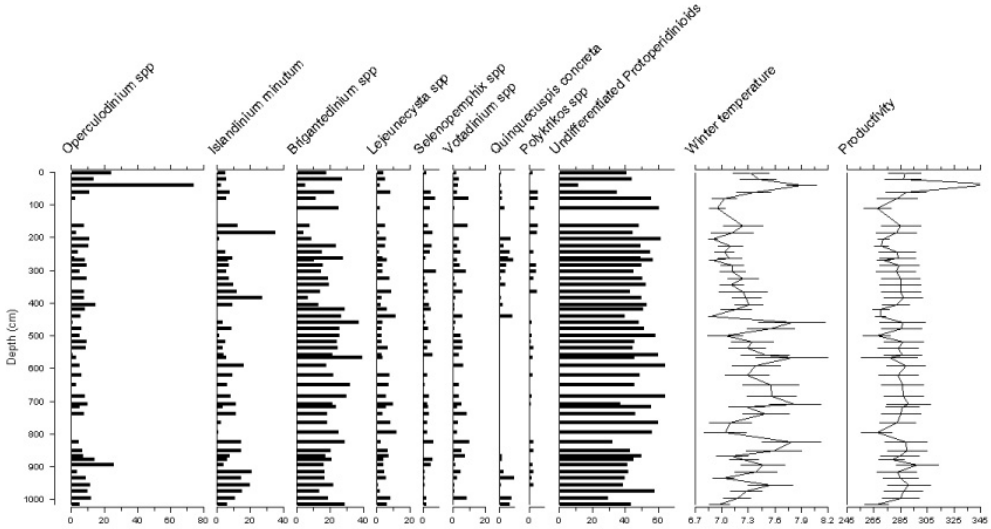


Fig. 3. Distribution of dinoflagellate cysts in Outer Basin core TUL 99 B11 and interpreted winter temperature and productivity through the core

Dinoflagellate Cysts as an indicator of potential introduction of invasive marine species in East and West coasts Canadian ports

Olivia Lacasse, André Rochon and Suzanne Roy

The constantly increasing transoceanic commercial shipping has become an important vector for the introduction of invasive marine species (IMS) since 1959. It has now become essential to evaluate the risks inherent to this kind of invasion in the Canadian marine habitat. One of the objectives of the CAISN (Canadian Aquatic Invasive Species Network) program is to identify the IMS already present in coastal and intertidal marine habitats, according to different sources and standards of propagule pressure. In order to do so, this study uses dinoflagellate cysts that are found in the sedimentary deposits of the main Canadian ports to assess any establishment of new dinoflagellate species in the past few years. Also, these living organisms found at the surface of the sediments, will serve to evaluate the actual propagule pressure. In a larger context, the aim of this study is to establish a list of the marine species that are present today in the Canadian waters.

Cretaceous dinoflagellates from Brazilian marginal basins

Cecilia Lana, Mitsuru Arai and Edwige Masure

Cretaceous dinoflagellate cysts from the Brazilian marginal basins (figures 1 and 2) have been systematically studied since the late 1980s. These data support a detailed comparison of the dinoflagellate assemblages recorded in the Brazilian equatorial margin (Ceará and Potiguar basins) and southeastern margin (Espírito Santo through Pelotas basins). The main differences in Cretaceous dinoflagellate assemblages along the Brazilian margin result from two major causes: on a global scale, the paleolatitudinal differentiation of the assemblages leading to a remarkable provincialism; more locally, distinct depositional and/or paleobathymetrical settings of the coeval marine strata. The oldest marine sections in the Brazilian equatorial and southeastern margin bear similar dinoflagellate successions. In equatorial basins, the base of this section (upper Aptian) comprises the *Subtilisphaera* spp. Ecozone, a unit still unkown to the south of the Espírito Santo Basin (Campos through Pelotas basins). In southeastern basins, the equivalent stratigraphic interval testifies to the widespread sedimentation of late Aptian evaporites under extremely arid climatic conditions. The lower to middle Albian of both margins is equally poor in dinoflagellates despite the conspicuous occurrence of the genus *Pseudoceratium*. The species *P. anaphrissum* prevails in the equatorial margin, but the genus displays higher diversity in the southeastern margin. The extinction of *P. anaphrissum* occurs within the middle Albian in basins of both margins. From late Albian times on, the differences between dinoflagellate assemblages from both margins become more apparent. The Campos through Pelotas basins are rich in dinoflagellates, and show successive extinction events (*O. diversum* and *G. coronata* in the upper Albian, and *L. arundum* in the lower Cenomanian). None of these species have been thus far recorded in the Ceará and Potiguar basins, where upper Albian rocks display relatively high frequencies of the genus *Oligosphaeridium*. Cenomanian rocks of the Ceará Basin are poor in dinoflagellates due to the prevalence of stratified, dysoxic water conditions, whereas in the adjacent Potiguar Basin the equivalent section records shallow shelf marine environments subject to strong nutrient supply, with productive waters and diversified dinoflagellate assemblages (*C. cooksoniae* Zone). Cenomanian zonal species of the southeastern margin, such as *P. cretaceum*, *E. dettmanniae* and *C. edwardsii*, are unknown in the equatorial margin. Neverthless, Cenomanian and younger sections of the southeastern margin also contain poor, low-diversity dinoflagellate assemblages in response to dysoxic water conditions, particularly within the upper Cenomanian-Turonian interval. The Turonian of the southeastern margin is characterized by two dinozones (*A. haromense* and *Cribroperidinium* sp. A). Both species are absent in the equatorial margin,

Figure 1 - Location map of the Brazilian marginal basins.

where coeval strata are poor in dinoflagellates, partly because of shallow water carbonate sedimentation (Potiguar Basin), and partly because of dysoxic deep water depositional conditions (Ceará Basin). The paleolatitudinal differentiation of the two margins becomes more pronounced from the Coniacian onwards. The cosmopolitan species *O. pulcherrimum* abounds in both margins from the Albian to the Santonian. However, three zonal species of the Coniacian-Santonian interval in the southeastern margin (*C. striatoconum*, *B. perforata* and *H. difficile*) do not occur in equatorial basins. The global distribution of *C. striatoconum* and *B. perforata* is typically austral. *N. aceras*, which is frequent in Santonian-Lower Campanian strata of the southeastern margin, is absent in equatorial basins.The provincial imprint on Cretaceous dinoflagellate assemblages of the Brazilian continental margin is more evident amongst the peridinioids. *S. cheit*, a common index species of lower to middle Campanian strata in the equatorial margin, is far less abundant in the southeastern margin. The upper Campanian-lower Maastrichtian interval of the equatorial margin records deeper water environments rich in peridinioid dinoflagellates, notably of the genus *Isabelidinium* (*I.* gr. *cooksoniae* Zone). This genus is also frequent in the southeastern margin, but here *O. costata* and *A.* cf. *rhomboides* are the zonal markers, and this zone top is at the Campanian/Maastrichtian boundary. Dinocyst assemblages of Brazilian basins are once again comparable in the Maastrichtian, when oceanic circulation between both margins became more effective.

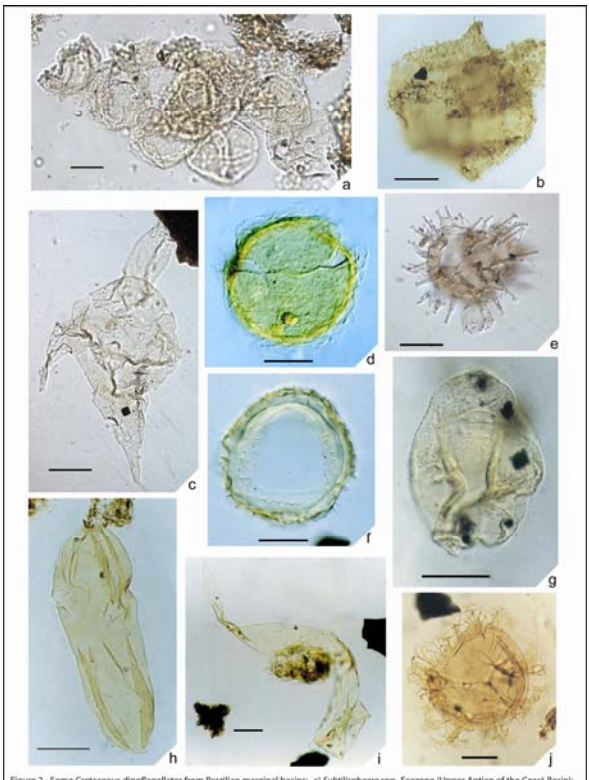


Figure 2 - Some Cretaceous dinoflagellates from Brazilian marginal basins: a) *Subtilisphaera* spp. Ecozone (Upper Aptian of the Ceará Basin); b) *Pseudoceratium anaphrissum* (Lower-middle Albian of the Ceará Basin); c) *Odontochitina ancala* (Upper Albian of the Jequitinhonha Basin); d) *Ovoidinium diversum* (Upper Albian of the Campos Basin); e) *Florentinia radiculata* (Cenomanian-Turonian of the Jequitinhonha Basin); f) *Trichodinium castanea* (Upper Cenomanian of the Potiguar Basin); g) *Isabelidinium* aff. *cooksoniae* (Lower Maastrichtian of the Ceará Basin); h) *Amphigymnium mitratum* (Campanian of the Ceará Basin); i) *Yolkinigymnium lanceolatum* (Maastrichtian of the Santos Basin); j) *Nematosphaeropsis "grandis"* (Lower Campanian of the Ceará Basin). Scale bar: 20µm.

Dinocyst assemblages as tracers of Holocene sea surface conditions in the main axis of the Northwest Passage: a comparison between the East and the Central Canadian Arctic Archipelago.

David Ledu, André Rochon, Anne de Vernal and Guillaume St-Onge

Instrumental data from the Arctic revealed a dramatic modification of the hydrographic parameters over the past 30 years. It is therefore of primary importance to better understand the climate variability in the Arctic, which cannot be assessed from short-term observational data, but require longer time series. We have consequently collected 4 piston cores (~ 6 m) for palynological analysis along the axis of the Northwest Passage in Lancaster, Barrow, Victoria and Dease straits. Here, we present the results of two cores 2004-804-009 and 2005-804-004, from Lancaster and Barrow Straits respectively.

Both cores have been sub-sampled every 10 cm for the analysis of dinoflagellate cyst (dinocysts) assemblages, which will allow us using transfer functions in order to reconstruct the sea surface hydrographic parameters. Radiocarbon ages indicate that both cores span the last 10,000 cal BP. The age model indicates variable sedimentation rates from 29 to 123 cm/kyr and from 28 to 122 cm/kyr for cores 2004-804-009 and 2005-804-004 respectively, allowing for a secular time-scale resolution of the Holocene climate oscillations. Grain size and geochemical analyses of core 2004-804-009 show a prevalence of the fine fraction in the major part of the core, indicating hemipelagic sedimentation. The base of the core records a higher percentage of sand and $CaCO_3$ and high values of the C/N ratio, which suggest an erosive dynamic with a large inflow of freshwater indicating a terrestrial sedimentation that we associate with meltwater inputs associated with the retreat of the Laurentide Ice Sheet.

Dinocyst analyses show a strong opposition between the two cores. The 2004-804-009 sequence shows four different zones. The first zone at the base of the core covers the late Pleistocene (13,387 to 12,500 cal BP) and indicates a maximum abundance of pre-Quaternary palynomorphs with an absence of

cyst in the lowermost 40 cm of the core consistent with a high meltwater input. The second zone covers the late Pleistocene to middle Holocene (12,500 to 8400 cal BP) and is dominated by the heterotrophic taxa *Brigantedinium* sp. and *Islandinium minutum*. The third zone covers the middle to late Holocene (8400 to 2750 cal BP) where the percentage of autotrophic taxa increases with *Spiniferites frigidus*/*elongatus, Operculodinium centrocarpum, Pentapharsodinium dalei*. The fourth zone covers the late Holocene to the modern conditions (2750 cal BP to present) with the dominance of heterotrophic taxa.
In contrast, core 2005-804-004 shows a dominance of the heterotrophic taxa *Brigantedinium* sp., *Islandinium minutum*, *Echinidinium aculeatum* in the major part of the sequence. A large increase of such taxa between 6600 and 5500 cal BP suggests a correlation with the third zone of the 2004-804-009 core. This zone is accompanied by an increase in both core of the reconstructed August T°C of about +3°C and a decrease of the sea ice cover of about 1.5 month/yr relative to modern conditions, suggesting the Holocene thermal optimum. We associate this period with a strong vertical mixing of Atlantic water in Barrow Strait due to Ekman pumping triggered by a possible shift in the Arctic oscillation at millennial time scale which enhanced upwelling and support heterotrophic taxa, while autotrophic taxa are limited by the thinning of the euphotic zone. From 5500 cal BP to present, the two sites show opposite trend (colder/warmer at Barrow Strait and warmer/colder at Lancaster Sound), which seems to underline the oscillation between positive and negative mode of the Arctic Oscillation that characterizes present day conditions.

Dinoflagellates newly recorded around Jeju Island of Korea and tropical species occurrence in response to global warming

Joon-Baek Lee, Hyeung-Sin Kim, Seung-Hyun Kim and Jin-Hwan Lee

Jeju Island is located at the southern part of Korea and placed at the East China Sea between the Changjiang estuary of China and the Kyushu Island of Japan. During the last 10 years we have identified 24 dinoflagellates which are newly recorded around the island, i.e. *Ceratium eniculatum, C. platycorne* var. *dilatatum, C. praelongum, Dinophysis cuneus, D. diegens, D. hastate, D. miles* var. *schroeteri, D. schuettii, Dissodinium elegans, Histioneis highleyi, Ornithocercus magnificus, Ornithocercus magnificus* var. *quadratus, O. magnificus* var. *steinii, O. serratus, O. steinii, Oxytoxum constrictum, O. scolopax, Podolampas bipes, P. palmipes, Protoperidinium steinii, Pseliodinium vaubanii, Ptychodiscus noctiluca, Pycocystis robusta, P. hamulus* var. *Hamulus.*

The adjacent waters of the island exhibit the influence of the Tsushima Warm Current which is a branch of Kuroshio Current. The ecosystem also shows subtropical and/or temperate characteristics. As the climate has been changed to be subtropical due to global warming, some tropical species have been easily observed among fishes, invertebrates, and even macro-algae in the coastal area. Thus we have tried to find out an evidence of such changes by monitoring the assemblage of dinoflagellates. Among the newly recorded dinoflagellates, we observed 14 tropical species, i.e. *Ceratium praelongum, C. eniculatum, C. platycorne* var. *dilatatum, Dinophysis schuettii, D. miles* var. *schroeteri, D. diegens, D. cuneus, Histioneis highleyi, Dissodinium elegans, Pyrocyst hamulus* var. *hamulus, Oxytoxum constrictum, Ornithocercus magnificus, O. serratus, Podolampas palmipes* . Most of them are newly recorded in Korean waters and originally found in tropics and even in Indian Ocean. The occurrence of these tropical species might be related to current changes of Kuroshio in terms of strength and direction, which happened by the changes of marine ecosystem due to global climatic changes.

Palynological investigation of the western Mexican coast

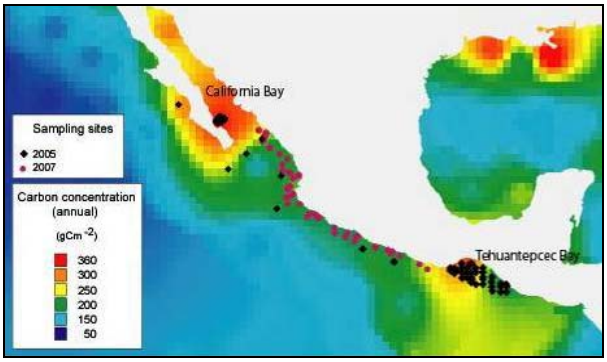
Audrey Limoges, Jean François Kielt, Taoufik Radi, Anne de Vernal and Ana Carolina Ruiz-Fernandez

The western Mexican coast is characterized by a primary productivity particularly high in upwelling areas: primary productivity reaches up to ~320-390 $gC \cdot m^{-2} \cdot yr^{-1}$ in the California Bay and to 120-360 $gC \cdot m^{-2} \cdot yr^{-1}$ in the Gulf of Tehuantepec. In order to document the relationship between productivity and dinocyst assemblages, we have started to develop a reference database from surface sediment samples (figure below).

The data available show concentrations of dinocysts of about 12 700 $cysts \cdot cm^{-3}$ in the California Bay decreasing towards the Gulf of Tehuantepec, where they are about 2000 $cysts \cdot cm^{-3}$. Both autotrophic and heterotrophic taxa are present in dinocyst assemblages. The heterotrophic taxa are dominated by *Brigantedinium* spp., *Echinidinium aculeatum*, *Echinidinium granulatum*, *Echinidinium* sp., *Selenopemphix quanta* and *Quinquecuspis concreta*. Among the autotrophic species,

Operculodinium centrocarpum, Spiniferites delicatus and *Spiniferites* spp. are the most abundant.

Heterotrophic taxa largely dominate in the areas where seasonal upwelling occurs. The California Bay is characterized by dominant *Polykrikos kofoidi*, whereas the phototrophic specie of *Polyspaeridium zoharyi* is relatively abundant in the Tehuantepec Bay. In contrast, autotrophic species (*Spiniferites* spp.) prevail in the southern part of the Gulf of Tehuantepec. *Bitectatodinium spongium* and *Brigantedinium* spp. are omnipresent along the western Mexican coast which is characterized by weak upwelling.



Small-scale turbulence: a new factor affecting parasite infection on dinoflagellates

Gisela Llaveria, Esther Garcés, Rosa Figueroa, Nagore Sampedro, Elisa Berdalet

The influence of turbulence on the infectivity of *Parvilucifera* sp. (an eukaryotic endoparasite of dinoflagellates) was experimentally investigated along a field dinoflagellate proliferation event dominated by *Alexandrium minutum*. The 15-60 µm microplankton fraction of the natural community was distributed in 4 litres spherical flasks containing f/20 culture medium and maintained still or exposed to the turbulence generated by an orbital shaker. The abundances of the most common species (*Alexandrium minutum*, *Scrippsiella trochoidea* and *Prorocentrum micans*), of *Parvilucifera* sp. sporangia (used as proxy of infectivity) and of *A. minutum* ecdysal cysts were estimated. This experimental design was performed three times, with inocula coming from different phases of the bloom, and thus with different phytoplankton composition and likely physiological state.

In all experiments, the development of *A. minutum*, *S. trochoidea* and *P. micans* populations under turbulence slowed down and stabilized as described in previous studies using the same design in absence of parasite (Bolli et al. 2007, Berdalet & Estrada 1993).

While no infection on *P. micans* appeared in any experiment or condition, *Parvilucera* sp. clearly infected *A. minutum* and *S. trochoidea* cells. Significantly higher infectivity accompanied by the collapse of the populations was observed in the still treatments compared to the shaken ones. Nevertheless, under turbulent conditions, when the abundances of these two species exceeded 10000 cells·mL^{-1} an outburst of infectivity also occurred with the subsequent decay of the dinoflagellate populations. These circumstances were encountered during the experiment conducted with the phytoplankton community obtained in the last phases of the bloom, previous to its decline.

In the case of *A. minutum*, its capacity to produce ecdysal asexual cysts along its life cycle did not appear to confer a particular resistance to infection. Indeed, considering the whole data set, high cyst abundances observed along the experiments were also accompanied by a high degree of infectivity.

Overall, the results suggest that turbulence can diminish parasite contagion within certain constraints imposed by the host cellular abundances and likely its physiological state.

Paleohydrology of the last 22,000 years in Marmara Sea and timing of the European ice sheet melting: a dinocyst perspective

Laurent Londeix

A Holocene brutal connection between the Aegean Sea and the Black Sea was first hypothesized by Ryan *et al.* (1997) who dated this catastrophic event at 7.150 ^{14}C yrs BP. This connection, often referred to the "Noah's Flood" as described in the Bible, was later described by Aksu *et al*. (1999) as a progressive infilling of the Black Sea starting at 9,000 ^{14}C yrs BP. The present study aims at improving our understanding of this major event, using dinocyst assemblages from the Marmara Sea as proxies of past hydrological conditions. The stratigraphic framework of the studied sedimentary core was precisely assessed by Vidal et al. (in press) who shows that this record accumulated continuously over the last 22,000 years. Dinocyst assemblages indicate that the Marmara Sea was subject to the alternative influence of fresh/brackish and salted waters from the Black Sea and the Aegean Sea, respectively. The delivery of melt waters (originating from the Fenno-Scandian ice sheet) to the Marmara Sea occurred in two steps from ~16.1 to ~13.7 ^{14}C ka BP, and from ~12.6 to ~11.5 ^{14}C ka BP, and was followed by the setting up of

present hydrological conditions in the Marmara Sea characterized by low salinity (12-13 ‰) in the surface layer and more salted marine conditions at the bottom. This marine influence reached episodically the surface waters only from ~11.0 ^{14}C kyrs BP and in a perennial way until Present from ~7.0 14C ka BP.

Dinocyst assemblages suggest that quasi-marine conditions occurred in the surface layer at the time of the M1 sapropel conditions between ~9.8 and ~5.8 ^{14}C kyrs BP, which contradicts the assumption of a strong run off from the Black Sea at that time (Aksu *et al.*, 1999).

Our study does not provide any evidence for a brutal flood event around 7,150 years BP.

Calibrated dinocyst events in the Miocene of Porcupine Basin, off southwest Ireland (IODP 307).

Stephen Louwye, Anneleen Foubert, Kenneth Mertens, David Van Rooij and the IODP Expedition 307 Scientific Party

IODP expedition Leg 307 recovered a Miocene sequence (160 m) from the upper slope of the Porcupine Basin off southwest Ireland in a water depth of 409 m. Core recovery was excellent and a high resolution palynological analysis revealed the presence of well-preserved dinoflagellate cysts, acritarchs and other organic-walled palynomorphs such as chlorophycean algae. The dinocyst association consists typically of oceanic and outer neritic species – reflecting the deep water depositional environment at the upper shelf slope – and inner neritic species swept in from the shelf. Shipboard and shore-based palaeomagnetic measurements were carried out on the Miocene sequence. Only the inclination data from the characterisitic remanent magnetizations were used for the construction of a palaeomagnetic framework, and dating was possible through correlation with the recently published ATNTS scale.

A late Burdigalian to late Serravallian age can be proposed for the Miocene sequence. The palaeomagnetic dating in combination with the data from a Sr-isotope analysis resulted in an age-depth model indicating an average sedimentation rate of 3.3 cm ka^{-1}. The age model allows proposing calibrated key ranges of selected dinocysts for the Lower and Middle Miocene interval. The dinocyst events are compared regionally through the North Atlantic realm and diachronicity is assessed through regional palaeoenvironmental and depositional circumstances.

The Curious Morphology of Some Late Albian Gonyaulacoid Dinoflagellates

Joyce Lucas-Clark,

Some exceptionally well preserved Gonyaulacoid cysts from Late Albian (mid-Cretaceous) rocks of Northern California show some unusual morphology studied with the light microscope (Differential Interference Contrast) and the Scanning Electron Microscope. *Gordiacysta coronata* is unique in its "trabeculate network" herein interpreted as an expression of paratabulation related to *Damassadinium*. Three (?) new species have in common a unique structure of the antapical and sulcal region consisting of an infundibulum and a claustral posterior sulcal region. They also have in common a cavate, anterior mid-ventral ridge that separates paraplate A (Taylor-Evitt notation) from paraplate 2 and may or may not represent paraplate 1u; a highly unusual arrangement of paraplates, similar, but not exactly like *Pentadinium*.

Another new gonyaulacoid species shows a curious development of crests that look as if they have been appressed to pandasutural bands. Furthermore, what appears to be cavation in this species is really a more complex feature. A new species of what may be termed *Hystrichosphaeropsis* has a fenestrate apical pericoel.

All specimens are from northern California localities in the Central Belt Franciscan and are extracted from calcareous concretions.

Organic-walled dinoflagellate cysts from Neogene strata, Northern Colombia

Fernando Mantilla Duran, Sandra Lucia Gazon Beltran and Vladimir Torres

Organic walled dinoflagellate cysts constitute an important biostratigraphic and paleoceanographic proxy, highly relevant on continental margins. Although a substantial amount of information is available from mid and high latitudes; data from tropical regions is sparse and mainly derived from West Africa. In order to contribute to a more global understanding of Neogene dinocyst assemblages, a composite section spanning the Early Miocene – Pliocene was generated using three wells located offshore Guajira, Northern Colombia. The age model for this section is based on foraminifera biostratigraphy. In preliminary results, dinoflagellate cysts species with documented biostratigraphic importance in mid and high latitudes as *Hystrichosphaeropsis obscura, Filisphaera filifera*

and *Selenopemphix dioneacysta* were found. Species as *Cordosphaeridium* sp, *Hystrichokolpoma* sp, *Lejeunecysta* sp, *Lingulodinium machaerophorum, Nematosphaeropsis* sp, *Operculodinium centrocarpum, Polysphaeridium zoharyi, Spiniferites* sp, among others, were also encountered in the analyzed samples. The results of this study will contribute to the generation of a regional zonation and to understand the response of dinocysts assemblages in the Miocene-Pliocene paleoceanographic changes related to the uplift of the Panamanian isthmus.

Early to mid Holocene organic-walled dinoflagellate cyst records from the eastern Mediterranean Sea: climate variability and productivity patterns of a "miniature ocean"

Gianluca Marino, Francesca Sangiorgi, Eelco J. Rohling and Henk Brinkhuis

The use of organic-walled dinoflagellate cyst (dinocysts) to reconstruct past sea surface conditions is gaining increasing attention in the paleoceanographic community. Here we exploit this tool to provide a detailed portrayal of the variations in sea surface productivity (SSP) and temperatures (SSTs) for key locations of the eastern Mediterranean (eMed) during the early to mid Holocene period of sapropel S1 deposition. Some dinoflagellates are heterotrophic and feed on other microplankton (e.g., diatoms) or organic matter. Accordingly, higher abundances of their cysts in the sediments may reflect enhanced eukaryotic sea surface productivity. The validity of this proxy for SSP reconstructions is still debated, as the majority of the heterotrophic cysts appear to be sensitive to oxic degradation, and better preserves under hypoxic conditions. We discuss heterotrophic cyst data from the Sicily Channel, Aegean and Adriatic Seas. Absolute abundance of heterotrophic cysts in the Aegean Sea reaches a maximum at ~10 ka BP, with concentrations that remain relatively high for ~4 kyr. Similar peak concentrations are reached only later in the Adriatic Sea (~8.5 ka BP). In the Adriatic Sea, the interval with average high absolute abundances of heterotrophic cysts is shorter and terminates at ~ 7.1 ka BP. Heterotrophic cysts concentration increases between 10 and 6.5 ka BP in the Sicily Channel. These data, which are further discussed with respect to the occurrence of oxyphillic benthic foraminifera in Adriatic and Aegean Seas during sapropel S1, show that heterotrophic cysts are a valuable proxy for SSP reconstructions. To discuss SST variability in the Aegean Sea during the early to mid Holocene, we selected the cold-water phototrophic dinocyst *Spiniferites elongatus*. Increases in this taxon parallel those of the non-seasalt potassium [K^+] in GISP2. Given that the latter is a proxy for the meridional character of the atmospheric polar vortex, the similarity with the *S. elongatus* record is indicative of the close link between the winter/spring Aegean coolings and periods of intensification and enhanced meridional displacement of the atmospheric polar vortex. We further discuss a particularly sharp Aegean cooling event between 8.3 and 8.15 ka BP, embedded within the general cooling episode of 8.6-8.0 ka BP. In both timing and duration, this sharp event agrees with the so-called 8.2 ka BP event identified in several records from the wider North Atlantic region and tied to a meltwater-forced reduction of the Atlantic meridional overturning circulation.

A two-step slow drowning of the Black Sea during the early Holocene

Fabienne Marret, Peta J. Mudie, Ali E. Aksu and Rick Hiscott

The recent debate regarding the rate and timing of the flooding of the Black Sea at the beginning of the Holocene has led to a multiproxy investigation in order to obtain a clearer perspective. Amongst the proxy studied for reconstructing past sea surface conditions, attention has been focused on organic-walled dinocysts, that fossilize well in sea floor sediments and which reflect a partial picture of the phytoplankton population. Dramatic changes in the specific composition of the assemblages clearly indicate major changes in sea surface conditions. A 9 m long core, collected in the SW shelf of the Black Sea covers the last ~9,300 years and has a decadal to centennial resolution, enabling us to investigate the timing of the changes from a brackish Neoeuxinian Black Sea to present-day conditions.

Two main assemblages, one dominated by brackish species, *Spiniferites cruciformis* and *Pyxidinopsis psilata*, and freshwater algae, and a subsequent one, characterised by euryhaline species (*Lingulodinium machaerophorum*, *Brigantedinium* spp., *Protoperidinium ponticum*), document a progressive change in sea-surface conditions from low saline (~7–12 psu) to present-day conditions. A first major pulse of marine waters is recorded at around 8.46 ka BP, with a maximum of *L. machaerophorum*. The occurrence of this species from the bottom of the core, dated at 9.3 ka BP, supports the hypothesis that water levels were already high on the southwestern shelf by that time. Fully

present-day conditions are recorded at around 5.6 ka BP, when brackish species and morphotypes of *Spiniferites belerius*, *Spiniferites bentorii* and *L. machaerophorum* disappeared. Arrivals of Mediterranean species (*Operculodinium centrocarpum* and *Spiniferites mirabilis*) are observed simultaneously in the southwest and southeast region of the BS at around 7 ka BP. Despite a different protocol for palynomorph preparation and presentation of data, previous studies from the northern shelf also document the arrival of euryhaline species at 7 ka BP, and marine influence prior to that time. The history of harmful algal blooms (HABS) shows a correlation with warmer mid-Holocene temperatures, followed by a succession of introductions possibly associated with early Greek exploration, then merchant shipping.

Dinocyst assemblages in the Black Sea - Mediterranean corridor

Fabienne Marret, Peta Mudie and Suzan Kohlief

Previous studies of temperate region modern dinocysts have focused on the deepwater assemblages of the western Mediterranean Sea (salinity 35-37) and the low salinity assemblages (16-25) of the Caspian-Black-Marmara Sea corridor. We will review these assemblage data and their correspondence with surface salinity and nutrients. Recently, we have also studied the dinocyst assemblages in surface samples from the shelf and slope of the saline (38-39), highly oligotrophic southern Levantine Basin off the Egypt, and we will compare these assemblages with those previously reported for the Syrian and Palestine shelves, and basins of the Aegean Sea. We find that there is a sharp transition from *Lingulodinium* – protoperidinioid dominated species on the inner shelf to *Impagidinium*- *Spiniferites* dominated assemblages on the upper slope and further offshore. Off the Nile Delta, there is little evidence of cross-shelf cyst transport, but along-shelf transport may be more important than salinity for palynomorph distribution.

Upwelling intensity and frequency off NW Iberia over the last 8000 years from a high resolution dinocyst record

Fabienne Marret, Stuart Whitfield, Leopoldo Pena and Guillermo Frances

A high resolution record of organic-walled dinoflagellate cysts provides evidence of rapid shifts in sea-surface temperature and hydrological conditions in the Ria de Muros, NW Iberia over the last 8200 years. This study, complemented with stable isotopic data from benthic foraminifera document 1.5 ka cyclicity related to the North Atlantic circulation. Influence of Eastern North Atlantic Water of subpolar origin (ENAWsp) and Eastern North Atlantic Water of subtropical origin (ENAWst) can be distinguished based on a ratio between "warm" dinocysts (*Impagidinium paradoxum* and *Spiniferites mirabilis*) and "temperate" dinocysts (*Nematosphaeropsis labyrinthus*, *Spiniferites membranaceus*, *S. ramosus* and *Impagidinium sphaericum*). Global climatic signals appear to be recorded by the dinoflagellate cyst cohort, such as the Bond events, the Roman Warm Period, the Medieval Warm Period and the Little Ice age. The temperature anomaly coinciding with the **RWP** may be linked to strong stratification in the outer Ria de Muros during a period of particularly wet climate in NW Spain.

Twenty years - *Alexandrium fundyense* bloom dynamics in relation to total phytoplankton community and environmental variables in the Bay of Fundy

Jennifer L. Martin, Murielle M. LeGresley and Fred H. Page

Phytoplankton abundance and a number of physical and chemical variables have been monitored at four locations in the Bay of Fundy at varying weekly to monthly intervals since 1987. Through the time series, *Alexandrium fundyense*, the organism known to produce paralytic shellfish poisoning (PSP) toxins, has occurred annually at all sampling sites. The date at which *Alexandrium* first appears in samples varies from mid-April to late June with the mean and median date of the first appearance of *A. fundyense* varying by only a few days between stations. The date of the maximum concentration of *Alexandrium* cells varies by about 30 days between stations and years with the maximum cell counts occurring earliest at the inshore estuarine station (June 20-24) and latest at the offshore station (July 15-22). The annual maximum concentration of *Alexandrium fundyense* varies from 140 - 23 000 cells cells•L^{-1} in the estuarine station to 2.2 x 10^3 - 5.0 x 10^6 cells cells•L^{-1} at the offshore site. The mean and median concentrations increase from inshore to offshore during most years. The duration of *A. fundyense* blooms ranged from 42 to 205 days between sites and years. The mean (median) duration of the bloom is 114 (112) days. *A. fundyense* blooms vary inter-annually with some blooms consisting of 1 to 3 events per year.

During most years and at all stations, *A. fundyense* cells were minor components (<50%) of the total phytoplankton community. This phenomena seems to be apparent for most sampling days except during rare years such as 1989, 2004 and 2007 when *A. fundyense* concentrations exceeded 1.0 x 10^5 cells•L^{-1} and when it was observed at these high concentrations it comprised 40-80% of the total phytoplankton community. Organisms that co-existed varied between years and locations. At concentrations >5.0 x 10^5 cells•L^{-1} the total phytoplankton community was often >75% *A. fundyense*. When comparing *A. fundyense* concentrations to total dinoflagellate cell densities during periods where maximum cell densities were observed, *A. fundyense* was not a major component (60-95%) of the dinoflagellate community during most years unless there were >1.0 x 10^5 cells•L^{-1}.

Preliminary results suggest that during years with colder February March temperatures the *A. fundyense* cell numbers are elevated. Additionally, concentrations exceeding >7.5 x 10^4 cells•L^{-1} appear to be linked to reduced nitrate levels. Results from the twenty year dataset indicate that high *A. fundyense* cell densities are required to make any linkages with environmental or physical factors.

Late Albian dinoflagellate cysts paleobio-geography as tracer of asymetric sea surface temperature gradients with southern high latitudes warmer than northern high latitudes

Masure Edwige and Bruno Vrielynck

The Middle Cretaceous represents a time of transition in the nature of the ocean-climate system with greenhouse conditions. Relatively flat sea surface temperature gradients (SST), suggesting export of heat to higher latitudes, have been estimated from $\delta^{18}O$ data. The flat SST is supposed to be responsible for very discrete latitudinal bioprovinces (ammonite, foraminifera, nannofossile). In order to define accurately the strategies of life of dinoflagellate species under greenhouse conditions, distribution maps have been drawn using thirty eight cysts recovered from about one hundred fifty outcrops and deep sea drilling ODP, DSDP sites located at low and high paleolatitudes (75°N-70°S). Fifty years of published data available in eighty seven articles have been considered and synthesized using a database coupled with a GIS "ArcGis ESRI software". The cretaceous climatic trend in distribution is seen best with stenotopic dinocysts (cool temperate/estuarine and tropical-subtropical/oceanic) as observed in modern sediments (Wall et al, 1977). The latitudinal ranges of sensitive species with temperatures define seven provinces, four on the Northern Hemisphere and three on the Southern Hemisphere. The continuous "equatorial" and "subtropical" belts extended respectively from 25°N to 40°S and from 45°N to 70°S. The "temperate" belts were discontinuous and restricted between 40°N-60°N and south 50°S. Taxa restricted to the higher northern latitudinal belt are not observed in the Southern Hemisphere. Biogeographic patterns facing "warm" and "cool" dinocyst assemblages reveal major frontal systems as paleosubtropical fronts. The well defined northern frontal system (40°N-45°N) was located as in the modern Ocean. The large southern frontal system (50°S-70°S) was 10°-20° poleward to Antarctica. Asymmetric latitudinal ranges of species constrained to subtropical water masses and asymmetric location of major fronts demonstrate asymmetric temperature gradients, steeper in the Northern Hemisphere and flatter in the Southern one, with southern high latitudes warmer than northern high latitudes. Joining dinoflagellate provinces and estimated $d^{18}O$ temperatures data from fish tooth (Pucéat et al., 2007), we suggest limit range temperatures for Mid-Cretaceous sensitive dinoflagellates and temperature gradients on both hemispheres. Stout belts gained from cysts support the ideas that, in spite of warmer sea surface temperatures, dinoflagellates were potentially far more sensitive to temperature than previously thought and steeper paleobiogeographic patterns do not support a thermal gradient linked exclusively to a colder climate mode. Our Mid-Cretaceous thermal gradient linked to a greenhouse conditions, with southern high latitudes warmer than northern high latitudes, appears to be the reverse of that of the modern cold period and implies that drastic changes in the global heat transport were required between the Northern and the Southern Hemispheres. The concept of an equable Cretaceous climate needs serious reconsideration.

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Re-examination of cyst-motile form relationships of *Polykrikos kofoidii* Chatton and *Polykrikos schwartzii* Bütschli (Gymnodiniales, Dinophyceae)

Kazumi Matsuoka, Hisae Kawami, Satoshi Nagai, Mitsunori Iwataki and Haruyoshi Takayama

We re-examined the cyst-motile form relationships of two *Polykrikos* species; *P. schwartzii* and *P. kofoidii* (Dinophyceae), based on a literature survey, incubation experiments, and molecular phylogenetic analysis. For the motile forms, the longitudinal furrows on the hypocone of *P. kofoidii* are the most important morphological feature differentiating from *P. schwartzii*. Surface different ornamentations of the cysts of *P. schwartzii* and *P. kofoidii* have been considered important morphological features differentiating between these two species. In the earlier studies on the cyst-theca relationship, the cyst of *P. schwartzii* is characterized by reticulate ornaments vs that of *P. kofoidii* by separate, rod-like processes. However, incubation experiments carried out in the previous study clarified that the *P. kofoidii* cyst has network ornaments, not rod-like processes. The different observations on these relationships suggested that rod-like processes are developed in not cysts of *P. kofoidii* but of *P. schwartzii*. The cyst-motile form relationships given by these studies are completely different from the earlier conclusion. Phylogenetic analysis on small subunit and large subunit rDNA sequences directly collected from vegetative cells and living cysts of *P. kofoidii* and *P. schwartzii* confirms the opposite finding to former taxonomic papers on this relationship. Also morphologically intermediate forms which sometimes occur are identical to the cyst of *P. schwartzii* based on the molecular data of a single cell PCR technique for living cysts.

Resting cysts of freshwater dinoflagellates in Severn Sound, Georgian Bay (North American Great Lakes): taxonomy, taphonomy, and paleolimnological applications

Francine McCarthy, Andrea Krueger, Heather Gregg and Martin J. Head

Despite large numbers of analyses from the Great Lakes catchment by several palynologists, the cysts of freshwater dinoflagellates are rarely reported. The discovery of a relatively diverse and abundant algal cyst flora, including several dinoflagellate cyst species assigned to the freshwater genus *Peridinium,* in late Holocene sediments from parts of Severn Sound was thus initially surprising. Algal blooms have, however, been noted historically in Severn Sound, which is an embayment of southeastern Georgian Bay (Lake Huron), making the occurrence of dinocysts less surprising. In addition, the dinocyst assemblage is similar to that found in small lakes on the shores of Severn Sound (Burden et al., 1985) and to that found in small lakes in the Lake Superior catchment in Minnesota by Norris and McAndrews (1970). Current work (Krueger, in prep.) is comparing the spatial and temporal distribution of algal cysts across Severn Sound (Gregg, 2006), with thecamoebian (testate amoeba) assemblages, with pollen zonation being the primary age control (McCarthy et al., 2007). Cyst preservation appears to be favoured by rapid burial (positively correlated with anthropogenic impact, initially by the Wendat (~A.D. 1450-1650) and subsequently by European settlers (beginning ~A.D. 1840). High organic carbon content of sediments and poorly oxygenated bottom water also appears to favour preservation of these thin-walled cysts. A detailed taxonomic study, examining the large degree of infraspecific variation in cysts attributed to *Peridinium willei, Peridinium wisconsinense* and *Peridinium limbatum,* will also be undertaken as part of this work.

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Using dinocysts to reconstruct late Cenozoic paleoenvironments on the New Jersey margin

Francine McCarthy, Sarah Tiffin, Miriam Katz, Jane Uptegrove, Greg Mountain

IODP Expedition 313 is scheduled to core the inner shelf off New Jersey late spring-early summer 2008- a goal that has thus far eluded the scientific community for many pragmatic reasons. The rapid depositional rates, tectonic stability, abundant seismic, well-log and borehole data available for the New Jersey margin make it ideal for

studying sea level change and its relationship to sequence stratigraphy. Because calcareous and siliceous planktonic microfossils are rare in these neritic sediments, age control and paleoenvironmental reconstructions rely largely on dinocysts and other palynomorphs, and on benthic foraminifera. The biostratigraphic zonation of de Verteuil and Norris (1996) has successfully been applied to correlating Miocene to Recent sediments from the Atlantic Coastal Plain to the New Jersey slope and rise (de Verteuil 1996, 1997; McCarthy and Gostlin, 2000, Tiffin and McCarthy, 2000; Tiffin, 2001) and to reconstruct paleoenvironments (McCarthy et al., 2000, 2003) in conjunction with other proxies such as benthic forams (Katz et al., 2003) and ichnofacies (Savrda et al., 2001). These previous studies will be used in order to achieve the major science goals of EXP 313: 1) to date major "Icehouse" (Oligocene to Recent) sequences and compare the ages of unconformable surfaces with sea level lowstands predicted from oxygen isotope data; 2) to reconstruct sea level change; and 3) to evaluate sequence stratigraphic facies models.

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The evolution of calcification in dinoflagellates: morphology, molecular genetics and geochemistry

Sebastian Meier

Calcification has evolved multiple times in many different branches of the eukaryotic part of the tree of life, and also one small sprig within the dinoflagellates has acquired this character during its evolution. The timing of this event has long been unclear, as some isolated records of microfossils with morphological characters attributed to the calcareous dinoflagellates, so-called calcispheres, are known from the Upper Triassic, whereas an uninterrupted record of undoubted calcareous dinoflagellates exists only since the Upper Jurassic. Molecular clock calculations with alternative calibration points for the origin of calcareous dinoflagellates indicate that a Jurassic origin is more likely than a Triassic one. This is in good agreement with traditional morphological dinoflagellate taxonomy, as the Triassic calcispheres show no indication of tabulation, whereas the true calcdino tabulation is remarkably stable over their evolutionary history.

The morphological variability is much larger within the calcareous stages than in the corresponding thecae, and splitting of taxa therefore occurs much more frequently in cyst based taxonomies. For modern taxa producing calcareous stages there are currently 3 theca-based genera with established cyst-theca relationships to 8 cyst-based genera, and an additional 8 cyst-based genera with unknown thecae. Molecular phylogenies indicate that calcareous dinoflagellates with 5 cingular plates (*Ensiculifera*/*Pentapharsodinium*) are probably ancestral, whereas those with 6 cingular plates (*Scrippsiella*) are derived, which is in accordance with the general theca taxonomy. The previous concept of classifying calcareous dinoflagellates by the crystallographic orientation of the crystals within the wall, however, is not well supported by molecular phylogenies on a first glance.

Calcification in calcdinos has evolved first in the diploid life cycle phase, and the majority of species investigated today forms diploid calcareous cysts. Diploid calcification was lost in a subclade of the calcareous dinoflagellates in which the haploid life cycle phase has diversified (including also *Pfiesteria*). Calcification was regained secondarily in two genera of this clade, and the vegetative calcareous coccoid cells are the dominant life-cycle

phase. Therefore, one part of the taxonomic confusion in calcareous dinoflagellates seems to result from comparing non-homologous calcareous structures, i.e. diploid resting cysts and vegetative coccoid cells.

Reinvestigating the ultrastructure of the calcareous walls in calcdinos is therefore urgently needed for a better understanding of unifying molecular, morphological and fossil phylogenies. First results show that the three major clades in calcareous dinoflagellates may be represented also by three different biomineralization modes. Unfortunately, the underlying biogeochemical processes are largely unknown. There are now first studies on the isotope chemistry of the calcareous wall of dinoflagellates representing different proposed biomineralization modes, and all of them show a characteristic strong depletion in $\delta^{13}C$ against equilibrium conditions in modern and fossil species, indicating highly specialized biomineralization pathways in calcareous dinoflagellates that are maintained despite the evolution of different modes of biomineralization.

Lingulodinium machaerophorum process length variations in the surface sediment: a salinity proxy?

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Process length variation of *Lingulodinium machaerophorum* has formerly been related to salinity variations in the Black Sea by Wall *et al.* (1973). This observation was confirmed by other micropaleontological studies (e.g. Turon (1984); Ellegaard (1998); Mudie et al. (2001); Leroy *et al.* (2006), Sorrel et al. 2006), and by culture experiments (Hallett 1999). The establishment of *Lingulodinium machaerophorum* process length as a salinity proxy represents a large potential for paleoenvironmental studies, since this species can be traced back to the Eocene (Stover *et al.*, 1996). The aim of the study was to evaluate whether the average process length shows a linear relationship with salinity, and to assess its validity as a salinity proxy. *Lingulodinium machaerophorum* cysts from surface sediments from the following areas were studied: Baltic, Norwegian Sea, Celtic Sea, Brittany, Portugese coast, Mediterranean, Marmara Sea, Black Sea, Caspian Sea, NW African coast, Canary Islands, Dakar coast, Gulf of Guinea, Caribbean, Monterrey Bay (California), Todos Santos Bay (Mexico) and Isahaya Bay (Japan). The 3 longest process lengths together with the body diameter of 50 cysts from every sample were measured for each sample. Process lengths of *Operculodinium centrocarpum* sensu Wall & Dale were used as a crosscheck. Results for the different geographic areas were compared to both SST and SSS (both seasonal and annual) at different depths at the locations, from the gridded ¼ degree Ocean Data Atlas (2005). The data suggests a basis for developing a SSS proxy based on process length of *Lingulodinium machaerophorum*, and indicates that depth and seasonality surely are also important factors in process formation. The use of this proxy is demonstrated using process length variation over time in different late Quaternary cores (GeoB7625-2 and BC53 (Black Sea), Limfjord (Denmark), GeoB5546 (Canary Islands), GeoB9064 (Cadiz), ODP976 (Alboran Sea), ODP1002C (Cariaco Basin) and M35003-4 (Grenada).The use of confocal microscopy to measure all processes on the cyst is explained, and opens new ways of methodological refinement. Surprisingly, distances between the processes are strongly related to process length, and this suggests very early predetermination of process formation. The study suggests a conceptual model of process formation.

The absolute abundance calibration project: the _Lycopodium_ marker-grain method put to the test

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Traditionally, dinoflagellate cyst concentrations are calculated by adding an exotic marker or “spike” (such as *Lycopodium clavatum*) to each sample following the method of Stockmarr

(1971). According to Maher (1981), the total error is controlled mainly by the error on the count of *Lycopodium clavatum* spores. In general, the more *L. clavatum* spores counted, the lower the error. A dinocyst / *L. clavatum* spore ratio of ~2 will give optimal results in terms of precision and time spent on a sample. It has also been proven that the use of the aliquot method yields comparable results to the marker-grain method (de Vernal et al., 1987).

Critical evaluation of the effect of different laboratory procedures on the marker grain concentration in each sample has never been executed. Although, it has been reported that different processing methods (e.g. ultrasonication, oxidizing, etc.) are to a certain extent damaging to microfossils (e.g. Hodgkinson, 1991), it is not clear how this is translated into concentration calculations. It is well-known from the literature that concentration calculations of dinoflagellate cysts from different laboratories are hard to resolve into a consistent picture. The aim of this study is to remove these inconsistencies and to make recommendations for the use of a standardized methodology.

Sediment surface samples from four different localities (North Sea, Celtic Sea, NW Africa and Benguela) were macerated in different laboratories each using its own palynological maceration technique. A fixed amount of *Lycopodium clavatum* tablets was added to each sample.

The uses of different preparation methodologies (sieving, ultrasonicating, oxidizing …) are compared using both concentrations - calculated from *Lycopodium* tablets - and relative abundances (more destructive methods will increase the amount of resistant taxa).

Additionally, this study focuses on some important taxonomic issues, since obvious interlaboratorial differences in nomenclature are recorded.

Microplankton from the Cretaceous Mannville Group, Northeast Alberta, Canada.

Daniel Michoux

The Early Cretaceous Mannville Group of western Canada corresponds to the oldest Cretaceous strata overlying the Paleozoic basement. It contains the main reservoirs of the northeastern Alberta heavy oil province. The basal oil-bearing sandstones of the McMurray Fm are overlain by Clearwater Fm, whose base consists of the glauconitic sandstones of the Wabiskaw Mb.

Previous work: The first accounts of the organic microplankton of the Mannville Group were published in the 1960's by Pocock[5], 1962, Singh[6], 1964 and Vagvolgyi and Hills[8], 1969. In 1971, Brideaux[1] and Singh[7] investigated its lateral equivalent in the Peace River area (Peace River Fm and Lower Shaftesbury Fm).

Present contribution: We illustrate here dinocyst assemblages recorded in the Mannville Group: McMurray Fm, Wabiskaw Mb and Clearwater Fm, based on boreholes from north-eastern Alberta. The distribution of organic microplankton is presented on a synthetic range chart, along with the percentage of marine microplankton and number of marine species. The main species are illustrated.

Palynostratigraphic calibration: The Clearwater Fm yielded species with well calibrated world-wide ranges: Litosphaeridium siphoniphorum has its stratigraphic inception in the Late Albian. *Ovoidinium verrucosum* has Middle to Late Albian stratigraphic base occurrence. *Stephodinium coronatum* is known from Albian or younger times. Several taxa whose geographic record seems restricted to high latitudes were recorded in the "upper" McMurray Fm and overlying units: *Ellipsoidictyum imperfectum*, *Gonyaulacysta hyalodermopsis*, *Leptodinium cancellatum*, *Pseudoceratium retusum*, *Pterodinium verrucosum*. Outside Alberta (Singh[7]), calibration points are provided by publications on the District of McKenzie: Brideaux[2] Brideaux & McIntyre[3], and the Canadian Arctic (Nohr-Hansen & McIntyre[4]). *Leptodinium cancellatum* and *Pterodinium verrucosum* were described in the Horton River Fm of the District of MacKenzie, assigned to the middle Albian. It was recorded in the early to late Albian of the Canadian Arctic. *Gonyaulacysta hyalodermopsis* was first described in the middle Albian of the District of MacKenzie and reported in the Aptian to early Albian of the Canadian Arctic. *Pseudoceratium retusum* was initially described by Pocock[5] as *Pseudoceratium pelliferum* in sediments from Alberta dated Aptian? and lower and Middle Albian. In the Peace River area, it ranges from the middle to the late Albian (Singh[7]).

Dinocyst assemblages: It is possible to informally subdivide the McMurray Fm into 2 units, based on their microplankton assemblages. Marine dinocysts are sporadic in the "lower" McMurray Fm (maximum of 8 species). The species present are *Oligosphaeridium complex*, *Palaeoeperidinium cretaceum*, *Canningia* cf. *colliveri sensu* Brideaux 1977, *Circulodinium brevispinosum*. Abnormal salinity taxa (*Nyktericysta* gp, *Vesperopsis mayi*) may be abundant. The most prominent feature of the "upper" McMurray Fm is the combination of diverse marine dinocyst assemblages and a significant amount of abnormal salinity taxa. The former group

includes cosmopolitan taxa: various *Oligosphaeridium* species, *Odontochitina*, *P. cretaceum*, as well as the "regional" taxa mentioned above: *E. imperfectum*, *G. hyalodermopsis*, *L. cancellatum*, *P. retusum*, *P.verrucosum*. The number of marine dinocyst species averages 27. Abnormal salinity taxa include mostly representatives of the *Nyktericysta* group and *Hystrichosphaeridium* sp. BE of Brideaux 1971. The *Nyktericysta* group all but disappears in the Wabiskaw Mb, where *P. cretaceum* has its maximum abundance. The Clearwater Fm is characterized by the very high frequency of *Canningia* cf. *colliveri sensu* Brideaux 1971.

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Taxonomy of the freshwater dinoflagellates, a time of changing concepts

Øjvind Moestrup

The freshwater dinoflagellates were monographed in 3 major works during the 1900s, each separated by 40 years: Lemmermann 1910 (79 species), Huber-Pestalozzi 1950 (164 species) and Popovský and Pfiester 1990 (177 species), the latter authors lumping numerous described species. In addition, Schiller in the 1930s produced his monumental work, covering both freshwater and marine species. These works were all based on morphology and utilized the morphological species concept. Sexual reproduction was known in few species only, preventing the use of the biological species concept. Ongoing work on a new flora of freshwater dinoflagellates has met with yet another challenge, a species concept based on molecular phylogeny. Related to the species concept is also the question of species biogeography. Are the morphospecies widely distributed and, if yes, should the genetic diversity found be reflected in the species concept?

Another problem is allocation of species to genera, families and phyla. I will in my presentation discuss some of the problems we are encountering, based on the organisms we have studied in most detail: the naked *Gymnodinium* and *Gyrodinium*, the thin-walled woloszynskioids (including *Sphaerodinium*, which has now been refound and isolated into culture) and the thecate *Peridinium*/*Peridiniopsis*. Separation into genera using the criteria from Ehrenberg/von Stein onwards to the present time is often not supported by ultrastructural and molecular evidence. Thus, as an example, the genus *Woloszynskia* is now being divided into five genera, separated by ultrastructure (eyespot structure, type of "apical furrow", etc), type of resting cyst and by molecular evidence. When a phylogenetically sound system has been constructed (comprising monophyletic genera) a very large number of the 250-300 known freshwater species will have changed generic name. A pragmatic approach is essential to retain the usefulness of the taxonomic system.

Morphological response of dinoflagellate cysts to oxygen-depleted environment during the OAE2 Event in the Great Australian Bight Basin, southern margin, Australia

Eric Monteil

In early 2007, Geoscience Australia conducted a geological and seepage survey in the Great Australian Bight Basin. The main objective of this survey was to improve understanding of the geological evolution and petroleum potential of the basin. The prime dredging target was the seaward edge of the Eyre Terrace where faulting, slumping and erosion in canyons provide access to rocks of Albian-Santonian age. The survey was successful and resulted in the collection of 37 dredge samples, 69 gravity cores and 15 grab samples, as well as 4600 kilometres of swath data and 2400 kilometres of sub-bottom profile data. A detailed analysis program was designed to integrate geochemical, biostratigraphical and paleoenvironmental data. Of the approximately 300 samples processed for palynological analyses, eight dredge samples were immediately singled out for their abundant organic matter content, which indicated anoxic depositional conditions. Based on the biostratigraphical schemes developed by Marshall (1984), Helby et al. (1987), McMinn (1988) and Partridge (2006), six samples were assigned a latest Cenomanian age while the other two were considered earliest Turonian. Less than 1% spores and pollen and an average of 45 dinoflagellate cyst species per sample were consistent with a distal marine environment. Results from organic geochemistry showed very high HI and TOC, up to 480 and 6% respectively, confirming the first evidence for the Cenomanian - Turonian oceanic event (OAE2) in the Great Australian Bight Basin. Each of these eight samples yielded a dominant and unique association

composed of morphological variants of *Cribroperidinium edwardsii* and *Cyclonephelium compactum,* and the species *Eurydinium ingramii* and *saxoniense*. Marshall and Batten (1988) had reported a very similar association from the Cenomanian - Turonian "Black Shale" sequences of Northern Europe, where assemblage composition was reported to vary according to lithofacies and palynofacies. Palynofacies containing abundant granular organic matter, which they interpreted as a depositional indicator of a stressed environment with low levels of oxygen extending up the water column, were also dominated by a *Cyclonephelium - Eurydinium* association. Elsewhere, the AOE2 event has also been linked with abundant *Eurydinium* specimens in the Southern Carnarvon Basin, North West Australia (Dixon, 2004), and with few specimens, tentatively attributed to *Ovoidinium ovale* prior to the erection of the species *E. saxoniense*, in the western North Atlantic (Herbin *et al.,* 1987). Mohr *et al.* (2002) identified the AOE2 event in the Central Kerguelen Plateau, Southern Indian Ocean, but did not place particularly emphasis on *Cyclonephelium* or *Eurydinium* species. However, the specimen illustrated as *Apteodinium* cf. *granulatum* is probably conspecific with the specimens of *C. edwardsii* var. A reported in this study. The global OAE2 event appears to have a similar palynological signature in the northern and southern hemispheres. In the Great Australian Bight this event is not only indicated by what now appears to be a typical dinocyst association but also by more subtle morphological variations which are interpreted to be the response of some dinoflagellate cysts to oxygen-depleted environment. Results are integrated with organo-geochemistry, and paleoenvironmental models and taxonomic implications are further discussed.

Harmful algae blooms in Manzanillo Bay, Mexico: a succession of dinoflagellates species in 2007

Alejandro Morales-Blake and David U. Hernández-Becerril

HAB in Manzanillo Bay, Colima, Mexico, are common phenomena during winter and spring, which from 1999 have become more intense (e.g. they remain longer periods and are more spread). In 2007 HAB started by the end of March and finished by June; during this period a succession of dinoflagellates species took place, firstly with naked forms, species of *Takayama* and *Karenia* (*T.* cf. *helix* and *K. bicuneiformis*, respectively), followed by *Gymnodinium catenatum*, *Cochlodinium polykrikoides, Ceratium divaricatum*, and then *C. polykrikoides*. These HAB were very dense and widespread (covering up to 10 miles off shore). The bloom caused by *Takayama* had not been previously reported, and it is speculated if this may be an introduced species by ballast waters, since the port of Manzanillo is a very large and important one. Fish mass kills were recorded during blooms of *Takayama* and *Cochlodinium polykrikoides*, whereas during the blooms dominated by *Gymnodinium catenatum*, high saxitoxin concentrations were detected in oysters, with no reported effects on the human populations. Oceanographic factors do play a significant role in HAB maintenance and dispersion in the Bay: preliminary models to describe the phenomena show that low turbulence and low superficial temperature are the initial conditions for HAB formation, and then a shallow thermocline, presence of internal waves, Langmuir circulation and density fronts contribute to keeping and spreading of these HAB. Additional observations in helicopter and analysis by remote images indicated the extension of the HAB in the study area.

Dinocyst of a cored Plio-Pleistocene transition from the Central North Sea

Dirk Munsterman and Roel Verreussel

A set of discrete core and side-wall core samples consisting of soft silts and clays from two closely spaced wells of the Netherlands Continental Shelf (southern North Sea) have been studied for dinoflagellate cysts. The high resolution study aims at the interval associated with the onset of northern Hemisphere glaciations, coinciding with the basal part of the Matuyama Chron. The Sea Surface Temperature (SST) signal extracted from the dinocyst distribution reveals a strong correlation with the cyclic pattern of the Gamma Ray log (GR). Warm phases (dominated by *Operculodinium israelianum* and/or *Lingulodinium machaerophorum*) correspond with low GR readings (predominantly silts); cold phases (dominated by the genera *Filisphaera*, *Habibacysta*, *Bitectatodinium* and/or *Brigantedinium*) correspond with high GR readings (predominantly clays). The Marine/Terrestrial ratio (M/T) also displays a strong correlation with the GR: low GR readings correspond with high M/T ratios, high GR readings with low M/T ratios. Reworked dinocysts are most abundant in the cold intervals. The results indicate that the coarsest sediments correlate with the warmest phases and the highest sea levels, while the finest sediments correlate with the coldest phases and the lowest sea levels. The distribution curves for the outer neritic to oceanic taxa *Amiculosphaera*

umbracula and *Nematosphaeropsis lemniscata* support that conclusion. The strong climate signal expressed by the dinoflagellate cysts is interpreted to reflect the 40.000 obliquity signal. Through extrapolation of the Gauss-Matuyama boundary, pin-pointed in one of the two wells, the displayed warm-cold cycles could be correlated to the marine isotope stages 103 to 95.

Integrated stratigraphical study emphasizing Miocene dinocyst distribution: Recent drilling of relatively well-developed marginal marine Miocene successions from the Dutch Southern North Sea Basin provided an opportunity to establish a first-ever dinocyst zonation for this region (SE part of the Netherlands). Recognition of consistent dinocyst events between multiple boreholes allow to propose fourteen zones for the Miocene. By combining information from calcareous microfossils, sequence stratigraphic analysis, and previous dinocyst studies, a meaningful age-model has been developed.

Fresh kleptoplastids of cryptophyte origin support the rapid growth of a DSP dinoflagellate species, *Dinophysis acuminate*

Geumog Myung, Hyung S. Kim, Na Ha, Myung Gil Park and Wonho Yih

D. acuminata strain KNU DA-MAL01, the first strain of *Dinophysis*, was established [1] by supplying a kleptoplastidic and mixotrophic ciliate *Myrionecta rubra* as prey. The prey *M. rubra* (strain KNU MR-MAL01) could grow well only when specific clade of cryptophytes such as *Teleaulax* sp. (strain KNU CR-MAL01) was again offered as its prey [2] as well as plastid donor [3, 4]. *D. acuminata*, therefore, should adopt the second-hand plastids of cryptophyte origin for its photosynthesis (=secondary kleptoplastidy). The time length between the ingestion of cryptophyte cells by *M. rubra* and the peduncle feeding on the ciliate cells [1] by *D. acuminata* (TL-MrDa) might be critical for the sustaining growth of *D. acuminata* through photosynthesis using the second-hand plastids. The TL-MrDa approximately represents the age of the adopted plastids since their last division inside the original cryptophyte cells: When starved (>4 wks) *M. rubra* were offered the growth of 2w-starved *D. acuminata* stopped after a few days of population increase, which is strikingly contrasted with the rapid growth of the 2w-starved *D. acuminata* on unstarved *M. rubra* cells. The 2w-starved *D. acuminata*, however, did not exhibit any notable growth when very long-starved (>8wks) *M. rubra* cells were supplied. Thus, the recycling frequency (= the inverse of TL-MrDa or the freshness) of cryptophyte plastids through cryptophyte-ciliate-dinoflagellate chain might be the leverage for the development of a sizable population of *Dinophysis* species in the sea

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Morphological variability within brackish water to marginal marine dinoflagellate cyst assemblages from mid–Cretaceous, West Greenland

Henrik Nøhr-Hansen

Palynological study of numerous samples from outcrops and boreholes representing the mid-Cretaceous (Albian-Turonian) sandy shale succession onshore West Greenland has revealed characteristic but very low diverse and low density palynological assemblages. The succession comprises floodplain, estuarine, innershelf /shoreface and subtidal delta deposits to more marine delta front/prodelta deposits.

The mid-Cretaceous deposits and its characteristic palynological assemblages are of importance in describing the deposition environment, and remarkable in for the first time demonstrating the transition from non-marine to brackish water deposits of Albian-Cenomanian ages to more marine deposits of Cenomanian-Turonian ages in West Greenland.

This work will show the morphological variability of the genera and assemblages within brackish water and more marine deposits, whether these variability's are of environmental, evolutionary origin or a combination, it is still discussed.

The palynological assemblages from the fluvial to estuarine deposits are totally dominated by spores, pollen and charcoal; whereas a few thin walled Ceratioid dinoflagellate cysts occur. The dinoflagellate cyst assemblage is represented by brackish water forms of the genera *Balmula*, *Nyktericysta*, *Vesperopsis*, *Pseudoceratium*/*Quantouendinium* and *Fromea*/*Wuroia*. Transition to more marine environmental deposits are characterised by the co-occurrences of the brackish water dinoflagellate cysts, common *Rugubivesiculites* pollen together with more marine indicatators like the dinoflagellate species *Odontochitina ancala*,

Rhombodella paucispinosa and *Subtilisphaera kalaalliti* indicating a late Albian to early Cenomanian age. The upper part of the mid-Cretaceous succession contain the fully marine species *Isabelidinium magnum*, *Palaeohystrichophora infusorioides*, *Surculosphaeridium longifurcatum* and *Heterosphaeridium difficile*, indicating a late Cenomanian to Turonian age. Ceratioid dinoflagellate cysts are common to abundant in non-marine to brackish water depositional environments in the mid-Cretaceous, almost world-wide. These characteristic morphological forms with a rather limited stratigraphic range are also flushed into marine environments and are therefore of great stratigraphic value in correlating and dating mid-Cretaceous deposits.

The brackish water indicators were originally described from fluvial to estuarine deposits of early late Albian age of the Western Interior, USA, later similar forms have been reported from brackish water deposits of mid-Cretaceous age from Alberta, Canada, Arctic Canada, Greenland and China.

Preliminary Miocene dinoflagellate cyst and acritarch biostratigraphy of a subtropical carbonate platform: ODP Site 1007, Bahamas

Manuel Paez, Martin J. Head and Hildegard Westphal

In 1996 Ocean Drilling Program (ODP) Site 1007 was drilled in 647.4 meters of water on the toe-of-slope of the Bahamas Platform to complete a transect across the bank and to improve the understanding of changing sedimentary environments associated with Neogene sea-level fluctuations on a passive carbonate platform. Samples from the lower part of Hole 1007C, consisting of monotonous alternations of cemented and uncemented fine-grained limestones of Miocene age, are being investigated for their dinoflagellate cyst content in order to document in a very resolved temporal network, subtropical Miocene dinoflagellate cyst associations.

Four preliminary biostratigraphic zones are proposed for the Miocene based on the presence of common and well-constrained bioevents previously recognized in middle and high latitudes. From bottom to top: Zone 1 (Upper Oligocene to Lower Miocene) is defined at the base by the last appearance datum (LAD) of *Hystrichokolpoma pusilla* and at the top by the consistent LAD of *Cleistosphaeridium placacanthum.* Within this zone occur also the LADs of *Cribroperidinium tenuitabulatum*, *Distatodinium paradoxum,* Acritarch sp. and *"Pyxidinopsis ovis"*, and the first appearance datums (FADs) of *Operculodinium*? *longispinigerum, Lejeunecysta marieae*, *Lavradosphaera*? sp. and *Impagidinium* cf. *aculeatum*. The base of Zone 2 (Lower Miocene) is defined by the top of Zone 1, and the top (lowest Upper Miocene) by the FAD of *Nannobarphora walldalei*. Other bioevents reported within this zone are the local FA of *Nematosphaeropsis labyrinthus*, *Selenopemphix quanta, Geonettia* sp. of Head (2000), *Operculodinium floridium*, *Operculodinium janduchenei* and *Melitasphaeridium choanophorum*. Zone 3 from lowest Upper Miocene to middle Upper Miocene is defined at the top by the FAD of *Geonettia clineae* and at the base by the top of Zone 2; a relatively low abundance of spiny small acritarchs, *Lingulodinium machaerophorum*, *Operculodinium centrocarpum* as well as cysts of *Pentapharsodinium dalei* and a moderate abundance of *Polysphaeridium zoharyi* and *Spiniferites* spp. are important features of Zone 3. Finally, Zone 4 is defined at the top by the FADs of *Nematosphaeropsis rigida* and *Nematosphaeropsis lativittatus* while the base is defined by the top of Zone 3. The LADs of *Lavradosphaera*? sp. and *Batiacaspahera sphaerica* were also recorded. Within this zone, tropical–temperate taxa such as the extant *Impagidinium paradoxum* and *Lingulodinium macharophorum* and the extinct *Operculodinium bahamense*, *Dapsillidinium pseudocollerigum* and *Nannobarborphora walldalei* were found in association with species of cooler-water affinities such as *Dallela chathamense* and *Nematosphaeropsis labyrinthus.*

Ongoing research will extend our record into the Pliocene in ODP Site 1007 and will explore changes in cyst assemblages associated with the closure of the Central American Isthmus as well as a result of periodic fluctuations in sea level during the Neogene.

Asexual Resting Cysts: A Common Dinoflagellate Survival Strategy?

Matthew Parrow and Anke Kremp

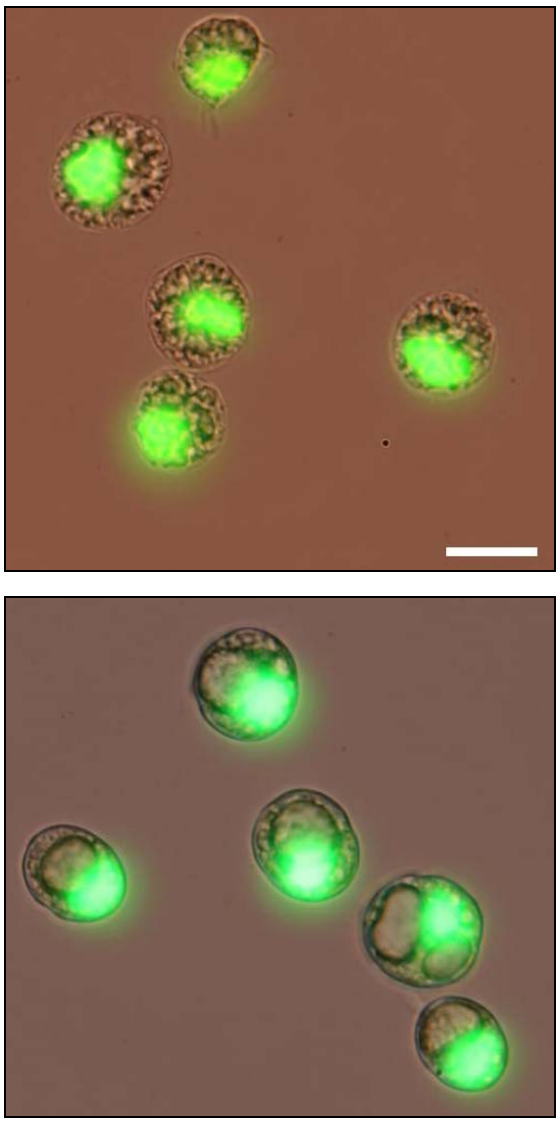
Formation of dormant, resistant stages that can survive conditions unfavorable for growth is a basic life cycle feature found in many protist groups, including ciliates, chlorophytes, chrysophytes, diatoms, and dinoflagellates. In dinoflagellates, these stages are commonly called resting cysts. Formation of resting cysts allows planktonic dinoflagellates in seasonably variable aquatic habitats to survive environmental conditions unsuitable for growth, and thus persist from one growing season to the next. The resting cysts of most dinoflagellate species are known

or presumed to be diploid zygotes (i.e. hypnozygotes) formed by gamete fusion in the sexual cycle, implying a requirement for sex in year-to-year survival. However, dinoflagellate species with substantiated sexual resting cyst formation are still relatively few compared to the total number of species known to form resting cysts. Therefore, it remains possible that some if not many dinoflagellate species may also produce asexual resting cysts that allow survival from one growing season to the next without requiring sex.

In previous research, we examined cyst dormancy and DNA content in *Scrippsiella hangoei* (Schiller) Larsen, a peridinoid dinoflagellate that grows during winter and spring in the Baltic Sea. This species produced resting cysts that were thick-walled and underwent a dormancy period of four months prior to germinating. However, the measured DNA content of the majority (>95%) of the resting cysts was equivalent to the lower, functionally haploid DNA content of asexually reproducing flagellate cells. These findings indicated that *S. hangoei* produces asexual resting cysts, and we proposed that asexual resting cysts might be a more common feature of dinoflagellate life cycles than previously thought.

In the present research, we tested this hypothesis by examining cyst dormancy and flagellate cell versus cyst DNA content in *Gymnodinium* sp. and *Woloszynskia halophila* (Biecheler) Elbrächter and Kremp, two species that co-occur with *S. hangoei* in the Baltic Sea. Both *Gymnodinium* sp. and *W. halophila* produced abundant cysts in culture. *Gymnodinium* sp. cysts were relatively small with a smooth, thin wall, whereas *W. halophila* cysts were relatively larger and covered with short spiny projections. Cysts of both species exhibited an endogenous dormancy period of approximately 6 months prior to germination, and thus were true resting cysts that likely function as inter-annual survival stages.

The relative DNA content of flagellate cells and cysts of *Gymnodinium* sp. and *W. halophila* were compared using a DNA fluorophore and flow cytometry. Cysts of both species required cell wall permeabilization prior to DNA staining. After treatment, both flagellate cells and cysts showed bright DNA-fluorescence localized at the cell nuclei (Figure 1).



Gymnodinium sp. flagellate cell population DNA distributions consisted of 1C, intermediate, and 2C DNA, indicative of respective eukaryotic cell cycle phases G1, S, and G2M, whereas *W. halophila* flagellate cells exhibited a single DNA peak distribution. Cysts of both species exhibited a measured DNA content overlapping that of the flagellate cells. The results of this study are discussed, along with theoretical considerations on methods and data interpretation in microfluorometric investigations of dinoflagellate cyst DNA content.

Neogene and latest Paleogene dinocyst and algal bioevents: preliminary results from three wells in the Beaufort-Mackenzie Basin, Arctic Ocean, Canada

Marion Grace Parsons and Geoffrey Norris

Major tectonic and climatic events influenced the composition of dinoflagellate assemblages in the Beaufort-Mackenzie Basin during the Paleogene-Neogene transition. A major widespread transgression beginning in the late Oligocene, an increase in communication between the Arctic Ocean and the North Atlantic, and a warming trend (with a thermal maximum in the middle Miocene) following an early Oligocene cooling would have contributed to the contrast between generally impoverished Oligocene dinocyst assemblages preceding the transgression, and the more diverse assemblages associated with Miocene deposits. During the Pliocene and early Pleistocene, assemblages in the study area yielded few marine dinocysts, but freshwater algae are more common. These are likely sourced from bogs or ponds associated with the large Iperk delta which developed at this time.

Dinoflagellate cysts and algae were examined from three wells in the Beaufort-Mackenzie Basin - Tarsiut A-25 (69° 54' 9" N, 136° 20' 20" W), Immiugak A-06 (69° 45' 2" N, 137° 00' 20" W) and Natiak O-44 (70° 3' 57" N, 137° 13' 6" W). These wells penetrate two or more of the following sequences: prodelta/shelf deposits associated with the latest Oligocene to middle Miocene Mackenzie Bay Sequence and the late Miocene Akpak Sequence, and delta front to prodelta deposits of the Pliocene-Pleistocene Iperk Sequence.

The Mackenzie Bay and Akpak sequences yielded dinocysts commonly reported from the Miocene - *Labyrinthodinium truncatum*, *Cleistosphaeridium placacanthum*, *Reticulatosphaera actinocoronata*, *Lingulodinium machaerophorum*, and *Cousteaudinium* spp. The *Batiacasphaera* group generally dominates the dinocyst assemblages from these two sequences while protoperidiniacean dinocysts appear to be absent. Other dinocysts are common in one well but absent or rare in the others. *Ataxiodinium* species, for example, have only been recovered from the Tarsiut A-25 well while *Platycystidia*? Species are commonly present in the late Oligocene and Miocene only in Immiugak A-06.

During the progradation of the Iperk Delta, there was extensive reworking of Mesozoic and Paleogene dinocysts. The Miocene dinocyst *Labyrinthodinium truncatum* is also probably reworked into the lower Iperk from the Akpak or Mackenzie Bay sequences. Rare indigenous dinocysts include *Filisphaera* species and *Pyxidiella* sp. A; the latter may be an endemic species associated with low salinity conditions. Algae such as *Halodinium minor* occur rarely, while spherical algal cysts (leiospheres) can be common in some wells. Freshwater algae such as *Pediastrum*, *Gelasinicysta*, and *Sigmopollis* are consistently present and indicate the proximity of freshwater environments.

Upper Jurassic – Lower Cretaceous dinoflagellate cyst biostratigraphy, palynofacies and paleoenvironmental interpretations in the area of Lake Hazen, Ellesmere Island, Canadian Arctic

Polina Pavlishina and Christo Pimpirev

Late Jurassic – Early Cretaceous dinoflagellate cyst assemblages are documented from three sections in the area of Lake Hazen, northeastern Ellesmere Island. These sediments have not been studied in details so far. The present contribution gives new data concerning the stratigraphy and in particular, palynological evidences for the age assessment of the succession cropping out along the northeastern slope of Lake Hazen. Two distinct dinocyst associations are recognized in the studied sections based on overall composition. The older, termed the *Gonyaulacysta dualis – Gonyaulacysta jurassica* Association defines Oxfordian age for the middle part of the succession, while the younger – the *Tanyosphaeridium magneticum* Association suggests Valanginian age for its upper part. The change in composition of the marine microflora and the overall palynofacies content are related to changes in depositional environments. The Oxfordian interval in the section is interpreted as representing continental, brackish to relatively shallow marine environments with a high influx of terrestrial organic matter. The association is dominated by *Gonyaulacysta representatives*, being characteristic to middle shelf environments with normal seawater salinity conditions. The subsequent Valanginian interval, which represents more open marine depositional environment, shows a higher species diversity and abundance of *Oligosphaeridium* species considered to be more typical for marine outer neritic paleoenvironments. In establishing this stratigraphic framework it was vitally important to compare the associations to the existing dinocyst framework for the Arctic, Boreal and Tethyan Realm and to utilize the cross ties between these provincially distinct zonations. The number of Boreal to Tethyan taxa is used to reflect changes in sea surface temperature.

Climatic and Paleohydrological interactions between the Mediterranean Sea and the Atlantic Ocean during the late Quaternary (last glacial cycle)

Aurélie Penaud, Frédérique Eynaud and Jean-Louis Turon

The glacial/interglacial cyclicity of the Quaternary as well as the abrupt climate events have deeply modified the Meridional Overturning Circulation. The production of deep-water in northern basins varied thus considerably. The active mechanism of the thermohaline circulation is primarily linked to the salinity budget of the North Atlantic, which itself depends on several factors; amongst these, it has been suggested that the Mediterranean Sea could act as a major trigger (Johnson, 1997; Voelker et al., 2006). Indeed, the Mediterranean Sea injects abundant saline water into the intermediate waters of the North Atlantic basins through the Mediterranean Outflow Waters (MOW). Some authors (e.g. Johnson, 1997) even suggest that the upwelling of MOW off Scotland could have diverted the North Atlantic Drift at times when the upwelling was extremely vigorous. Conversely, North Atlantic surface waters penetrate the Mediterranean Sea and impact on the hydrology of the whole basin. Understanding the relationships that link the Atlantic and the Mediterranean basins is therefore essential in order to constrain better the coupling between these two adjacent systems and their hydrological response during abrupt climatic changes.

We have centred our study on the area that directly connects the two basins. Two cores have been analysed from each side of the strait of Gibraltar. Core MD04-2805 (34°30'.99N; 7°00.99W; 859 m water depth; 7.72 m length) has been recently retrieved from the northern Moroccan margin and permits the investigation of the dynamism of the upwelling occurring on the African north-western margins. Core MD95-2043 (36°8.6'N; 2°37.3'W; 1841 water depth; 36 m length) is located in the central Alboran Sea. A multiproxy investigation has been conducted on the two cores. The present work focuses on the evolution of dinoflagellate cyst assemblages to assess tentatively prevailing surface-water conditions.

Core MD04-2805 covers at least the last two Heinrich Events (HEs). Our multiproxy record reveals different hydrographical conditions for HE 1 and HE 2. HE 1 is marked by a plateau of heavy planktonic δ13C values that may be a consequence of a higher productivity in the surface waters. At the same time, we can note the occurrence of heterotrophic dinocysts that are indirect proxies for a higher productivity, and a plateau of high values of Pinus pollen concentration (Fig. 1).

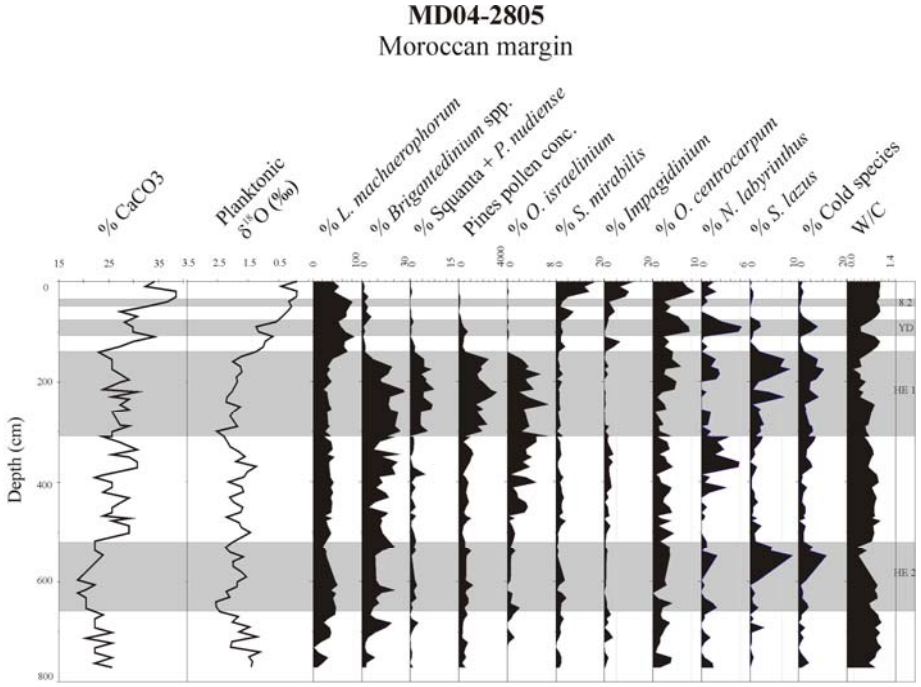


Figure 1

This could be the result of stronger northern winds bringing these pollen grains and also increasing upwelling cell strength off Morocco responsible for the high productivity. Another interesting finding is the occurrence of the dinocyst S. lazus during HEs whereas, northward, in peri-Iberian waters, it is the taxon *B. tepikiense* which generally marks these events (Fig. 2). This could indicate the presence of a strong hydrological barrier off Morocco.

The Alboran core covers the last five HEs and has been the subject of numerous studies (e.g. Cacho et al., 1999, 2006). Here, we contribute complementary information between HE 3 and HE 5 by adding dinocyst data to the rich list of proxies already analysed. Alkenone derived SST reveal the complete succession of stadial and interstadial periods over the last 50 ka, with occurrence of *N. pachyderma* s. during cold HEs. Our dinocyst record depicts comparable alternation of warmer and colder events (HE/DO; Fig. 3). Among the most noticeable features, *B. tepikiense* and *S. elongatus* are well correlated with cold events.

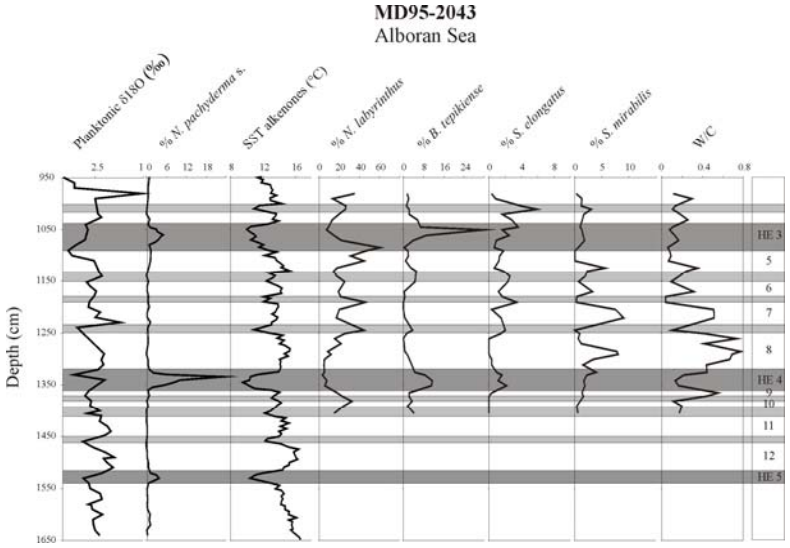


Figure 2

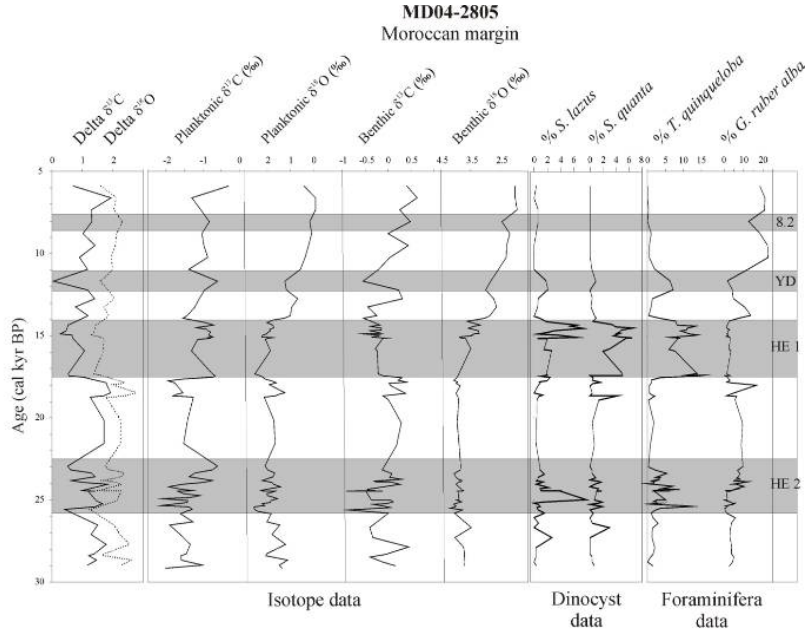


Figure 3

Near-shore dinoflagellate cysts assemblages of the late Tyrrell Sea phase at Old Factory Lake, eastern James Bay, Québec

Florin Pendea, Vera Pospelova and Gail L. Chmura

Previous studies of early Holocene deglaciation of northern Québec imply that the Old Factory River watershed (between Eastmain-Opinaca and La Grande Rivers) was flooded by the Tyrrell Sea as early as 8000 yrs. B.P. Isostatic rebound then forced a rapid marine regression throughout the area. Little is known about the paleoecological conditions of coastal waters during this period of shoreline retreat.

Our investigation on the southern shore of Old Factory Lake found a former marine terrace covered by late Holocene forest peat. We are conducting palynomorph analyses of the uppermost 17 cm of the marine layer. Relatively low diversity of dinoflagellate cysts was observed with a total of 13 morphotypes belonging to seven genera. Cysts of *Spiniferites spp.* are dominant (40-60%) accompanied by relatively high abundance of *Pentapharsodinium dalei*, *Operculodinium centrocarpum* and *Spiniferites ramosus.* Gonyaulacoid species dominate the dinoflagellate cysts assemblage (97-99%). Among the protoperidinoid species only *Islandinium minutum* has abundances > 1%. The Old Factory Lake fossil dinocyst record shows marked differences when compared to northern near-shore postglacial assemblages from the Hudson Bay region. The absence of arctic morphotypes (e.g., *Islandinium? cezare*, *Operculodinium centrocarpum* – arctic morphotype) could suggest warmer sea surface conditions in the former James Bay (southern Tyrrell Sea) compared to the former Hudson Bay (northern Tyrrell Sea). Relatively high cyst concentrations, ranging between 2 x 10^4 cysts cm^{-3} and 6 x 10^4 cysts cm^{-3} could suggest high levels of marine primary productivity. Further investigation of other postglacial near-shore sediments from eastern James Bay region will try to inform on the nutrient status, salinity and temperature.

The use of marine sediment for determining *Alexandrium* distributions

Linda Percy, Deana Erdner, Donald M. Anderson and Jane Lewis

The life cycle of the marine dinoflagellate *Alexandrium* includes an over-wintering resting cyst stage within the sediment and a vegetative stage within the water column, which in the UK generally occurs in early summer. However, when prior knowledge of *Alexandrium* occurrence at a site is limited, it is difficult to discern the exact timing of when cells may be in the water column and thus when to collect samples for identification and speciation. As such, using only samples collected from the water column for mapping of distribution may prove to be misleading. A more appropriate (integrated) method to help study the distribution of this genus is the collection and analysis of sediment in which the *Alexandrium* cysts potentially occur.

Analytical methods for determination of cyst presence within sediments include microscopy, sediment slurries for cyst germination and cell culturing and also molecular techniques, such as real-time PCR. There are benefits and difficulties of each technique. During the SEED project (funded by the EU and the US NSF), we have been investigating several of these molecular methods, focusing on the distribution of two "ribotypes" of *Alexandrium tamarense* (Western European and North American) from around the British Isles. This has additional complications as vegetative cells and resting cysts of both ribotypes are morphologically identical. Here we will outline the methods we have employed (germination of slurries, real-time PCR) and our experiences with using them.

Postglacial to Holocene environmental change in the Canadian Arctic Archipelago: a multiproxy sediment record from eastern Barrow Strait

Anna Pienkowski, John England, Fabienne Marret and Frédérique Eynaud

A continuous sedimentary record (>5.5m long), retrieved by the Geological Survey of Canada Atlantic from eastern Barrow Strait, Northwest Passage (MacLean *et al.* 1989), is currently being investigated for a suite of proxies in order to assess environmental changes since the last retreat of the Laurentide Ice Sheet (ca. ≥ 10 ka bp; Dyke 2004).

Results on the palynology (dinocysts, non-pollen palynomorphs or NPPs), foraminifera and ice-rafted detritus (IRD) present in the core (86027-144 piston and trigger weight) show several prominent environmental changes. Extrapolation of the radiocarbon dates suggests commencement of regional deglaciation at *ca.* 11.3 ^{14}C ka BP, and a transition from glaciomarine to postglacial conditions at ca. 10.2 14C ka BP.

Extremely sparse and impoverished dinocyst assemblages indicative of cold waters and lowered salinities (*Echinidinium karaense*, *Islandinium cezare*), an absence of NPPs and foraminifera, along with increased amounts of IRD suggest harsh conditions upon initial deglaciation. Thereafter (*ca.* 10.9-7.4 ^{14}C ka BP), increasing concentrations and higher species diversity of dinocysts, along with low amounts of IRD indicate more favourable conditions. Although dinocyst assemblages are dominated by typical high-latitude species (*Islandinium minutum*, *Brigantedinium* spp.), minor frequencies of subpolar taxa are present. Two prominent peaks in the occurrence of planktonic foraminifera during this period suggest a heightened influence of oceanic waters in this area.

Two intervals of reduced summer sea-ice-cover are implied at *ca*. 7.4-6.3 ^{14}C ka BP and *ca*. 3.7-2.0 ^{14}C ka BP. Both periods show a near absence or reduction of *Brigantedinium* spp. and increase in autotrophic taxa (e.g. *Spiniferites*). The latter period of decreased sea-ice cover is consistent with data from adjacent McDougall Sound (Blasco *et al.* 2005). After *ca.* 2.0 ^{14}C ka BP, dinocysts show a low-diversity polar assemblage dominated by heterotrophs (*I. minutum*, *I. cezare*, *Brigantedinium* spp., *Polykrikos* sp. Arctic morphotypes), similar to modern assemblages found presently within the archipelago (Mudie and Rochon 2001).

Forthcoming radiocarbon dates and δ^{18}O analyses on foraminifera will further constrain the chronology of this record and supplement existing data derived from dinocysts, palynomorphs, foraminifera and IRD. Collectively, these proxies will further elucidate whether the marine record corresponds to the deglacial/postglacial history primarily derived from terrestrial work (from geomorphology/radiocarbon dating of mollusks and whale bones found on raised postglacial shorelines). This research constitutes part of a broader study of glaciation, sea-level adjustment and environmental change under J. England's NSERC Northern Chair program, directly complementing other on-going research on adjoining Melville, Eglington, Prince Patrick and Banks islands.

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Evidence for Late Quaternary Climate and Marine Productivity Changes along the California Margin

Vera Pospelova and Thomas F. Pedersen

The sedimentary records of dinoflagellate cysts and foraminiferal organic linings from Ocean Drilling Program Holes 1017E (California Margin) and 893A (Santa Barbara Basin) indicate strong response of marine productivity to major shifts in climate and ocean circulation along the California Margin over the past 42 kyr. Throughout the sequences, dinoflagellate cyst assemblages are dominated by upwelling-related taxa, indicating the continued influence of coastal upwelling on the Margin during the Late Quaternary. The cyst records suggest that marine productivity was enhanced during the Holocene and Bolling, and to a lesser extent, during the Last Glacial Maxima and Dansgaard-Oeschger events, while an apparent reduction in productivity can be seen during the Younger Dryas. Comparison between these two sedimentary records allows us to identify local and regional paleoenvironmental signals. For example, the Allerod manifests itself in the enhancement of local marine productivity in the Santa Barbara Basin compared to a regional signal from the California Margin.Our results also indicate noticeable climate variability during the Holocene in this region. Application of the modern dinoflagellate-cyst assemblage-database from the Northeastern Pacific quantitatively indicates that Holocene summer sea-surface temperature and annual marine productivity varied over dynamic ranges of ~13-15ºC and 230-330 gC m^{-2} yr^{-1}, respectively.

Genetics and cyst-theca relationship of the arctic dinoflagellate cyst *Islandinium minutum*

Éric Potvin, André Rochon and Connie Lovejoy

Resting cysts produced by dinoflagellates, an important group of phytoplankton, are used as paleoecological indicators of sea-surface conditions in the Arctic. Knowledge of the ecology of dinoflagellates is mainly restricted to cysts settled in

surface sediments or motile forms living the upper part of the water column. The unification of these could draw a better picture of the relationships between the species and the environmental factors. However, little is known on the link between the cysts and the motile forms that produce them, especially for the Arctic environment. In this study, we chose to work with the dinoflagellate cyst *Islandinium minutum* because of its importance to reconstruct the duration of seasonal sea-ice cover in the Arctic area. To determine the relationship between *Islandinium minutum* and its motile form, genetics on individual cysts and morphological analyses on the motile form will be used. For the genetic analyses, each cyst will be washed, broken and transferred in a sterile tube. A fragment of the genome of *Islandinium minutum* will be amplified, sequenced and compared to fragments from different motile forms. Because genetic characteristics do not change through the life cycle of a species, this could lead to the identification of a motile form. For the morphological analyses, cysts of *Islandinium minutum* will be incubated in a F/2 medium at 4°C and at a light:dark cycle of 18:6, and emerged or excysted motile forms will be described. To determine morphologically the motile form, the theca, outer cellulose skeleton composed of multiple plates, will be described. In order to facilitate the observations of the theca, the plates will be coloured using calcofluor white. Once the organisation of the thecal plates is known, we will be able to assign the motile form to an existing one, or describe a new one.

Quantitative reconstructions of oceanic paleoproductivity using dinocysts: the approach and application to the Last Glacial Maximum in the northern North Atlantic

Taoufik Radi and Anne de Vernal

In order to develop a proxy of past productivity, we explored the possibility of using the assemblages of organic-walled dinoflagellate cysts (or dinocysts) in marine sediment. Dinoflagellates represent an important part of the primary production in the ocean, and their populations that include both phototrophic and heterotrophic taxa seem to depend upon the trophic structure of upper water masses. We used dinocyst data from 1171 surface sediment samples from the North Atlantic, Arctic and North Pacific oceans. For each site, we compiled two sets of primary productivity data derived from satellite observations: (1) The dataset from the Coastal Zone Color Scanner (CZCS) program applied to observations from 1978 to 1989 and (2) the data set from the MODerate resolution Imaging Spectroradiometer (MODIS) program using observations from 2002 to 2005. The results of canonical correspondence analysis (CCA), performed with 57 dinocyst taxa and 8 sea-surface parameters (winter and summer salinity, winter and summer temperature, sea-ice cover, summer, winter and annual primary productivity), show that primary productivity is a determinant parameter of dinocyst assemblages. We tested the modern analogue technique (MAT) for quantitative reconstruction of productivity based on dinocysts. The error of prediction (Root Mean Square Error = RMSE) is about ±15-25%, depending upon the productivity dataset. The best performance is obtained for winter productivity using the MODIS data. It is noteworthy that the RMSE for all estimated productivity parameters is narrower than the mean differences between productivity data derived from the MODIS and CZCS datasets. Therefore, we conclude that dinocysts can be used to reconstruct productivity with reliability as good as possible given the uncertainty inherent to primary productivity estimates from satellite observations.

The MAT has been applied to North Atlantic time series and led to reconstruct large amplitude variations of productivity over the last 25 000 years. However, the amplitude of reconstructed changes differs significantly depending upon the reference productivity dataset. The use of both MODIS and CZCS datasets indicates generally low productivity during the glacial stage, especially during the Younger Dryas and Heinrich events, with annual productivity of less than 100 gC m^{-2}. The reconstructions also suggest higher productivity during the early Holocene, especially based on the MODIS data that suggest annual values of up to 350 gC m^{-2}. Past productivity estimates using MODIS data for the LGM are more consistent with simulation of the North Atlantic Ocean productivity in the hypothesis of reduced Atlantic Meridional Overturning (as during the LGM) using a coupled climate-ecosystem model (Schmittner, 2005).

Reference:
Schmittner, A., 2005. Decline of the marine ecosystem caused by a reduction in the Atlantic overturning circulation. Nature 434, 628-633.

Siblings, cousins and marine relatives of the freshwater dinoflagellate Peridinium aciculiferum – a study in genetic diversity

Karin Rengefors, Ramiro Logares and Anke Kremp

A fundamental question in ecology is whether microorganisms exhibit biogeographic patterns. Although views differ, data is still very limited. Even less is known about the biogeography of Lake Phytoplankton, as well as about the genetic diversity within populations. Previous to the advent of molecular tools, species that looked alike were considered to be the same, and phytoplankton populations were thought to be composed of one or a few clonal lineages. Here I will present some of our findings on a freshwater dinoflagellate species and its close relatives. *Peridinium aciculiferum* is a widespread and winter-blooming freshwater dinoflagellate in Northern Europe and N. America. Due to its occurrence in winter, little was known regarding its ecology until recently. We have found that *P. aciculiferum* belongs to a species complex which has diverged recently, and includes sibling species in the sea, brackish-water, and in saline Antarctic lakes. These species are closely related to the marine-brackish toxic *Pfiesteria* species complex. We have also analyzed population genetic structures using DNA-fingerprinting techniques. High genetic diversity was detected within lakes, but no apparent geographic differentiation was obvious among the strains. In contrast, patterns in an Antarctic lake species tentatively suggest a pattern relating to habitat. We hypothesize that species can be widespread, but that genetic diversity along with habitat isolation, may lead to species divergence and potentially biogeography.

Protoperidinium minutum **from Portugal (NE Atlantic) – cyst-theca relationship and phylogeny as inferred from SSU and LSU rDNA genetic sequences**

Sofia Ribeiro, Nina Lundholm, Ana Amorim and Marianne Ellegaard

This work combines a detailed examination of the cyst-theca relationship of *Protoperidinium minutum* and the first phylogenetic study of this taxon, based on SSU and LSU rDNA sequences obtained through single-cell PCR.

Protoperidinium is a heterotrophic marine genus with more than 200 recognized species. About 25% of the species in this genus are known to produce cysts, a higher percentage than the estimated 13-16% for the entire dinoflagellate group (Head, 1996).

Round brown spiny cysts of unknown biological affinity have been recorded in surveys around the world and some of these morphotypes have been formally described and assigned to the cyst-based genera *Echinidium* (theropylic archeopyle) and *Islandinium* (saphopylic archeopyle). It has been suggested that species of these genera have biological affinities within the Family Protoperidiniacea (including *Protoperidinium*) (Zonneveld, 1997; Head et al., 2001), but cyst-theca relationships have not yet been formally established.

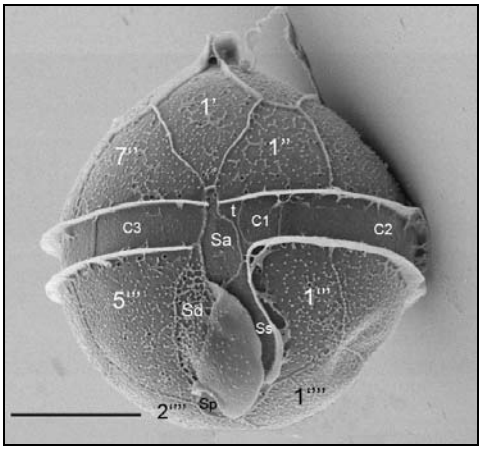
Several cyst types assignable to *Echinidium* and *Islandinium* have been observed in Portuguese coastal areas (Amorim, 2001; Ribeiro and Amorim, 2008). In order to help clarify the cyst-theca relationships and taxonomy of this poorly-resolved group, surface sediment samples from the Portuguese coast were screened for viable cysts and one common yet undescribed morphotype was studied in detail.

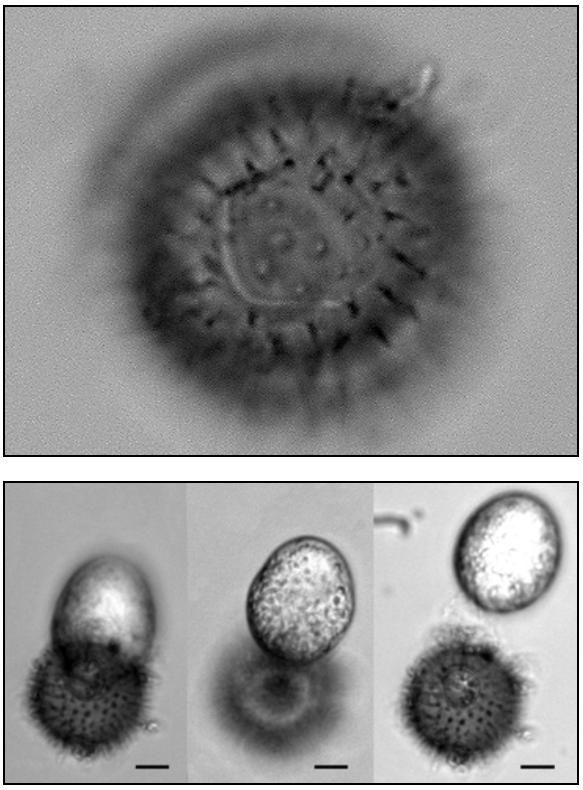
Several germination experiments were set at 15˚C with a total of 172 single cysts isolated into microwells with growth medium (salinity 25). Germination success rate was 60% within the first 72 hours. Careful examination of the hatched cells using light microscopy and SEM led to the identification of the motile stage as *Protoperidinium minutum*, subgenus *Archaeperidinium*.

Protoperidinium minutum has a complicated taxonomic history, and some authors have suggested it to be a species complex (e.g. Zonneveld and Dale, 1994). This species complex might be composed of several closely-related *taxa* exploring different ecological niches and possibly producing morphologically distinct cyst types, but with similar theca morphology.

Cyst-theca relationship examinations coupled with molecular methods have proven useful in identifying species-complexes of other dinoflagellates (e.g. Ellegaard et al., 2003).

Single-cell PCR, a method suitable for obtaining nucleotide sequences of heterotrophic dinoflagellates (that are generally difficult to maintain in culture) was used in this study. Results on the molecular phylogeny inferred from small and large subunit rDNA genetic sequences will be presented.





Dinoflagellate cyst assemblages from two contrasting sites in the Azores (Portugal) - Horta Bay and D. João de Castro Seamount

Sofia Ribeiro and Ana Amorim

This work resulted from an expedition to the Azores on board of "NTM Creoula" in summer 2005, organized by the Portuguese Navy, the Portuguese Federation for Underwater Activities (FPAS) and National Geographic Portugal. Surface sediment samples were collected from two contrasting sites: Horta Bay, a natural sheltered embayment with an important commercial and recreational port, and D. João de Castro Bank, a shallow seamount with hydrothermal activity and virtually no human impact. Samples were collected respectively by snorkelling and SCUBA diving, and kept cold and in the dark until processing, to prevent cyst germination. Laboratory procedures involved wet sieving of ca. 20ml of sediment per site and concentration by centrifugation using a heavy-liquid, to maximize the recovery of the cyst fraction. Permanent slides were mounted with aliquots of the rich cyst fraction and examined under the light microscope. The presence of cell contents was registered and assumed to be an indicator of recent cyst production. Sediments from Horta Harbour were fine and silty while at D. João de Castro Bank the recovered sediment was almost only volcanic rock and debris. Samples were poor, and a total of 201 cysts belonging to 15 different taxa were recovered. The 2 sites had a similar species richness (S=11) but different trophic and taxa composition. The embayment sample (Horta Harbour) was rich in *Protoperidinium* and *Scrippsiella*-like cysts (with no calcareous walls probably due to dissolution) having a balanced proportion of heterotrophic (45%) and photosynthetic (55%) species. By contrast, the seamount sample was largely dominated by autotrophs (93%), mainly *Protoceratium reticulatum*, *Spiniferites* and *Scrippsiella.* The percentage of cysts with cell content in Horta Harbour was 36%, against 67% for D. João de Castro Bank. These differences reflect the contrasting nature of the two sites. Horta Harbour lies inside a natural sedimentary basin where cyst production, transport and sedimentation are integrated in space and time. By contrast, due to erosion and re-suspension, the cyst community in D. João de Castro Bank reflects mainly recent cyst production. Wall et al. (1977) studied a sample from a harbour in the Azores (Ponta Delgada, São Miguel Island) and reported calcareous cysts (*Scrippsiella trochoidea*) as dominant. These authors observed *Protoceratium reticulatum* maximum abundances in shelf and slope-rise zone sediments. The fact that D. João de Castro Bank was dominated by recently formed cysts of this species suggests that this seamount constitutes an ecological niche which favours coastal-oceanic transition species. This study, although limited in time and space, gives an insight into the dinoflagellate cyst assemblages of the Azores. Further work is needed in this region to better resolve the taxonomy and ecology of this group and determine the ecological role of seamounts.

Paleoceanographic studies of the impacts of natural and anthropogenic perturbations in three Labrador fjord ecosystems (Nachvak, Saglek and Anaktalak): Preliminary results

Thomas Richerol, Reinhard Pienitz and André Rochon

We present the preliminary results of sedimentological, geochemical, and biostratigraphic analyses performed on three short sediment cores from three fjord ecosystems located along Labrador's East coast, sampled in November 2006 from CCGS Amundsen. Labrador Inuit depend on the sea and sea ice for their hunting and harvesting activities. They are concerned about the ecological integrity of the marine environment of northern Labrador especially with respect to the impacts of climate change,

industrialization (maritime navigation, mining) and contamination of their traditional foods.

The cores have been analyzed for various physical and chemical properties, such as sediment density, magnetic susceptibility and contaminant levels. The biostratigraphic analyses involved sediment sub-sampling at 1-2 cm intervals to determine changes in the composition and concentration of fossil diatoms and dinoflagellate cysts (dinocysts) throughout the cores. These are two important proxy indicator organisms in marine environments that allow for reconstructions of past climatic and environmental trends (e.g. changes in sea-surface temperature and salinity, sea-ice duration and ocean productivity) in both pelagic and benthic habitats. The chronology of each core has been established based on ^{210}Pb radioactive decay in the sediments and on AMS-^{14}C dates on marine shells preserved within the sediments.

The cores retrieved from northernmost pristine Nachvak fjord, next to the Torngat Mountains National Park Reserve, will be used to study the natural variability of environmental conditions in Labrador fjord ecosystems, while serving as a reference for the assessment of human-induced perturbations in the two other southern fjords (Saglek and Anaktalak). Saglek fjord sediments have been contaminated with PCBs (PolyChloroBiphenyl) due to erosional inputs from a former military site. We will try to track the ecosystem response to this kind of contamination by comparing pre- and post-perturbation conditions. The Anaktalak fjord is extensively used by Inuit for harvesting and traveling. Since the beginning of mining activities by the Voisey's Bay Nickel Company (VBNC), the fjord's Anaktalak Bay has received mining effluents and wastes from shipping. This project aims at determining the impacts of these activities, as well as developing appropriate indicators for the long-term monitoring of the environmental and ecological conditions within this fjord ecosystem.

***Protoperidinium canadiense*, sp. nov. (Dynophyceae): A new dinoflagellate species from the Canadian Arctic**

André Rochon and Eric Potvin

The dinoflagellate cyst (dinocyst) species *Islandinium minutum* has a widespread distribution throughout the Arctic and sub-arctic regions and is part of a group of morphologically similar species including *Islandinium cezare* and several species of the genus *Echinidinium*. *Islandinium minutum* comprises up to 90% of the dinocyst assemblages in surface sediments from northern Baffin Bay, the Canadian Arctic Archipelago, Fram Strait area and the Kara Sea. Up until now, the cyst-theca relationship of this species still remained unknown.

In 2005, surface sediment samples rich in viable *Islandinium minutum* cysts were collected from Lancaster Sound in the eastern Canadian Arctic Archipelago during an ArcticNet oceanographic campaign. The samples were collected using a boxcorer, and the upper 0.5 cm of the sediment surface was transferred in Whirl Pack bags and stored in the dark at 4ºC for further analyses. Back in the laboratory, viable *Islandinium minutum* cysts were isolated from the sediment using a hand-held micropipette and transferred into well plates containing 2 ml of F/2 – silica culture medium. They were then incubated in a Sanyo environmental chamber at 4ºC with a 18:6 light:dark cycle.

The cells of *Protoperidinium canadiense* sp. nov. are armored (avg. 42.5 µm L and 40 µm W). The epitheca is slightly larger than the hypotheca. The plate tabulation pattern is: PO, X, 4', 2a, 7'', 4c (3 + t), 5s, 5''', 2''''. The cell is globular with a low apical horn and no antapical spine. The shape of apical plate 1' is "ortho" (contacts four major epithecal plates) and the intercalary plate 2a is hexagonal. An apical pore complex is present. The cingulum is equatorial, excavated and not displaced. The sulcus is not excavated and ornamented with a fin on the left side. The surface of the theca is smooth and ornamented with pores and short (<1 µm) spinules or verrucae-like projections (scabrate). Cell content is greenish yellow and lacks chloroplasts. One of the main features of this new species is the organization of the intercalary plates. The intercalary plate 1a contacts 7 plates from the apical, precingular and intercalary series. In particular it contacts the first precingular plate, which is unusual within the genus *Protoperidinium*. So far, no dinoflagellate with such thecal pattern has been reported from any Arctic or sub Arctic locations. Further analyses of this new species will involve sequencing the SSU rDNA, and part of the LSU rDNA. Similar analyses will also be performed on several brown spiny cyst morphotypes/species, in order to determine their affinities and develop a phylogeny for the group of "brown spiny cysts".

Neogene Palynostratigraphy and Paleoenvironment in the Arctic Ocean and adjacent Nordic Seas: preliminary results

Michael Schreck and Jens Matthiessen

During the IODP Expedition 302 ("ACEX"), Neogene sequences were successfully drilled for the first time in the Central Arctic Ocean. Despite comprehensive magnetostratigraphic, radioisotopic and biostratigraphic studies, the chronostratigraphy remains problematic because the magnetostratigraphy did not provide unequivocal results and the low-resolution ^{10}Be stratigraphy could not be tied to an independent biostratigraphic framework.

Palynomorphs possibly provide the only age control in these largely biogenic carbonate and silica-free hemipelagic sediments but definite age assignments are hampered by absence of a consistent palynostratigraphy for the polar high northern latitudes. To overcome this obstacle, Neogene sequences in the Nordic Seas (ODP Sites 907, 908, 909), which are located on a transect from the seasonally-ice covered western Nordic Seas to the perennial ice-covered Arctic Ocean, are currently studied to calibrate palynostratigraphic datums versus magnetostratigraphy that might be useful to improve the age assignments in the Central Arctic Ocean. Although Neogene sequences were successfully drilled during ODP Legs 104, 151 and 162 in the Nordic Seas in the past decades, the long-term paleoenvironmental evolution in these high northern latitudes is virtually unknown. Therefore these sites will additionally be used to reconstruct sea-surface conditions in the period between ~16 and 3 Ma. Emphasis will be in particular placed on well-known paleoclimatic events such as the mid-Pliocene warm period that have been recorded in circum-arctic marginal marine sediments but could not be identified in the adjacent deep-sea.

Numerous potentially valuable palynomorph datums have been identified in Site M2A but comparison with occurrences at other high latitude sites is presently hampered by taxonomically problematic taxa and an inconsistent stratigraphic framework of ODP holes from the Atlantic sector of the high northern latitudes. These specific problems of high latitude palynostratigraphy are illustrated in this poster presentation by describing the biogeographic and stratigraphic distribution of a number of palynomorph taxa and by discussing the implications of revised datums for high latitude chronostratigraphy.

Topsy-turvy wall development of a new Down Under dinocyst genus: phylogenic and taxonomic implications

Natalie Sinclair and Eric Monteil

Very well preserved palynomorphs recovered from Oxfordian sediments of the Northern Carnarvon Basin (North West Shelf, Australia) have enabled new insights into the wall structure and development of processes and trabeculae of certain dinoflagellate cysts. An unusual wall relationship has been identified from a dinocyst complex with extreme morphological variability, encompassing cysts ranging from proximate to skolochorate and trabeculate to non-trabeculate. Based on this wall relationship a new dinocyst genus has been erected (Sinclair & Monteil, *in prep.*). Proximate morphotypes are moderately alike in appearance to *Lanterna*, and proximochorate morphotypes show similarities to *Amphorula* and *Oligosphaeridium.* Skolochorate morphotypes have strong affinities to genera such as *Oligosphaeridium* and *Rigaudella*, however morphological characteristics intrinsically associated with this particular wall relationship are comparable to features described on other published taxa, such as *Perisseiasphaeridium* and *Kilwacysta*. This suggests the simultaneous existence of two distinct skolochorate phylogenetic lineages. These new findings have the potential to significantly improve our current knowledge and understanding of skolochorate cyst phylogenetic lineages.

Paleo-monsoonal reconstruction using phytoplankton dynamics: A case history from Harshad Estuary, Saurashtra coast, Gujarat, India

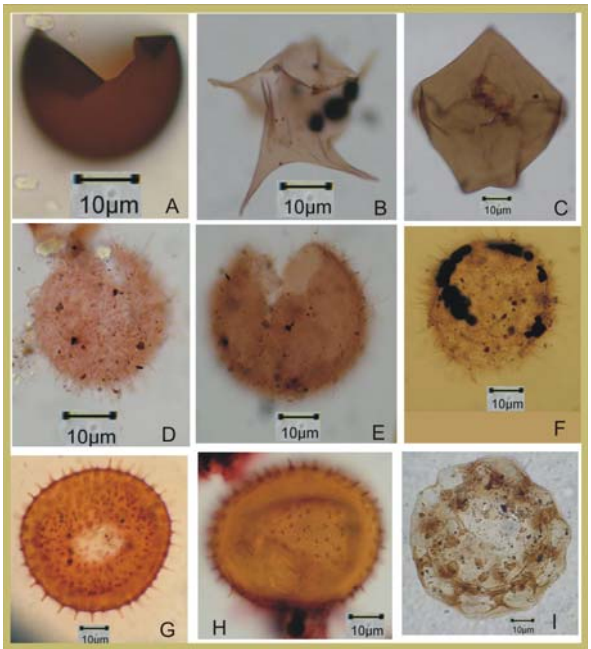
Vartika Singh and Vandana Prasad

Western coastal region of Saurashtra, Gujarat lies in the semi arid climatic zone and receives annual precipitation 300-250mm. Due to the low gradient coastline and lack of active river drainage system the region is characterized by extensive development of tidal flat with numerous, shallow, restricted environment i.e salt pans, small bays, lagoons and estuaries. Phytoplanktons (dinocyst and diatoms) being important constituents of photic zone are considered, tracer for various environmental parameters like salinity, pH, temperature, turbidity and nutrient status. High nutrient loading as a result of river runoff makes estuarine environment ideal for the phytoplankton (dinocyst and diatoms) growth. Hence the quantitative and qualitative distribution study of phytoplankton in the estuarine sediment can provide good proxy signal for monsoonal fluctuation of the past.

Harshad estuary that lies in the northwestern part of Saurashtra coast is a small restricted environment, is fed by ephemeral Vartu River and

becomes active only during active summer monsoon (SW) period (June-Serptember).

In the present study Phytoplankton (dinocyst and diatoms) distribution pattern was studied on the surface as well as down core sediments of Harshad estuary to assess the possible relationship amongst various phytoplanktons and to reconstruct a paleoprecipitaion fluctuation in this region. A sixty cm core was raised from the middle part of the Harshad estuary and sampling was done at one cm interval in order to achieve high resolution paleoclimatic interpretations. The sediments were studied for dinoflagellates, diatoms, phytoclasts and zooclasts. Amongst the dinoflagellate cysts both Gonyaulacoid and Protoperidinoid dinocyst occur in moderate numbers of which tropical dinoflagellate cyst *Bitectatodinium spongium* (Gonyaulacoid dinocyst) is the most dominant species throughout the core. Protoperdinoid (heterotrophic) dinocysts show high diversity pattern than abundance and show positive correlation with the pennate diatoms. Amongst the both centric and pennate diatom pennate diatoms occur in large proportion. The study of the sediment core has revealed significant variations in distribution pattern of different phytoplankton groups mainly the dinoflagellates and diatoms at various depth levels and four climatic phases were identified. **The Phase 1** (60-57 cm depth) corresponds to dominance of diatom population over dinoflagellates. High diatom counts signify increased levels of nutrients in the form of silica brought to the estuary by an increased run-off as a result of high monsoonal activity. **Phase II** (57-47 cm depth) is characterized by decrease in diatom and dinoflagellate cyst, low productivity due to low river discharge as result of low SW monsoonal activity. **Phase III** (45-25 cm depth) shows an increase in protoperidinoid dinocysts and fresh water pennate diatoms like *Gyrosigma, Surirella, Bidulphia* etc. This indicates high productivity as a result of high monsoon related run-off activity. **Phase IV** (20 cm to the top) is indicated by a sharp decline in diatom population, but significant increase in dinoflagellates as result of increased stratification conditions due to anthropogenic influence and possibly due to increased warming of surface waters in recent years.



(A- C) Protoperidinoid Dinocysts,
(D-F) Gonyaulacoid Cyst (*Bitectatodinium spongium*),
(G,H) *Operculodinium sp.*,
I - *Tuberculodinium vancampoae*

Late Holocene sea-surface conditions in the Newfoundland region based on dinoflagellate cyst assemblages.

Sandrine Solignac, Marit-Solveig Seidenkrantz, Antoon Kuijpers, Simon Troelstra, Catherine Jessen, Anja Grunvald, Esben Villumsen Jørgensen, Eva Zilmer Christensen, Monica Palitzsch and Andrea Fischel

The Labrador Sea occupies a central position in large-scale North Atlantic atmospheric circulation patterns and storm activity, and also plays a major role in the climate system through the transportation of polar waters and icebergs towards the south and the formation of deep water. A thorough assessment of the climatic changes that took place in this area is therefore of utmost importance in order to improve our understanding of the causes and consequences of such changes, in the past as well as in the future. Notably, several marked centennial-scale climate variations in the late Holocene (Roman Warm Period, Dark Ages, Medieval Warm Period, Little Ice Age) might have had significant impacts on early human settlements from Greenland and Newfoundland. It highlights again the need for more detailed paleoenvironmental records of the natural climate variability from the Labrador Sea area.

Here we aim at reconstructing late Holocene sea-surface conditions near Newfoundland. Today this region is characterized by the southward-flowing, polar water-carrying Labrador Current, which eventually meets the warm and saline North Atlantic Current. It also lies in the path of the North Atlantic cyclone track. Changes in oceanic or atmospheric circulation should therefore be effectively recorded in this sensitive region. As part of the multiproxy NEWGREEN project, we will analyze dinoflagellate cyst assemblages from several high-resolution cores retrieved in Bonavista Bay, Trinity Bay and Placentia Bay (northeastern, eastern and southern Newfoundland, respectively) and spanning the last 5000 to 10,000 BP. Comparison of the dinoflagellate cyst assemblages with XRF data, pollen records, archaeological data and other proxies will allow us to compare marine and terrestrial records and to assess the linkages between atmospheric processes (wind transport, etc.), oceanic changes (with special attention paid to sea-ice extent) and the history of human settlements.

Late Miocene dinoflagellate cysts of the Vienna Basin: an endemic Paratethyan assemblage

Ali Soliman and Werner E. Piller

Lake Pannon (Upper Miocene; Pannonian) formed at about 11.6 Ma in place of the relic Central Paratethys Sea framed by the Alps, the Carpathians and the Dinarids (Piller et al., 2007). Its geodynamic history and the gradual freshening of the water body led to the evolution of a highly endemic fauna and flora (Magyar et al. 1999a). A palynological study of the clay pit Hennersdorf, Vienna Basin, revealed endemic Paratethyan dinoflagellate cysts. The taxa composition of the dinocyst assemblage is particularly interesting. Cysts are present throughout the section and well preserved, but species diversity is low. The investigated materials are confined to the Middle Pannonian *Spiniferites paradoxus* Biochron sensu Magyar et al. (1999b). The dominant morphotypes are cysts of *Spiniferites, Impagidinium, Selenopemphix, Batiacasphaera* and *Pyxidinopsis.* However, there are some other rare Miocene dinocyst taxa e.g. *Operculodinium*, *Polysphaeridium*, *Lingulodinium* and *Melitasphaeridium*. It is, however, difficult to decide if they occur autochthonously or reworked. Their bad preservational state points to a reworked occurrence. A point of interest is the reported morphological variability observed in *Spiniferites bentorii* (Rossignol) Wall and Dale, 1970. In particular, the shape and size of the cyst, its processes, and development of the apical boss have been described as very variable. Such variations have been used to differentiate several subspecies as *Spiniferites bentorii oblongus, Spiniferites bentorii pannonicus, Spiniferites bentorii granulatus, Spiniferites bentorii coniunctus* and *Spiniferites bentorii budajenoesis*. To achieve a finer paleoecological record and to study the morphological variations of *Spiniferites bentorii,* a series of cores have been taken along the Hennersdorf section. Each core (ca. 50 cm) was cut into samples of 5 mm thickness. In the current study, core #1 at the base of the section, where a coquina horizon is detected, was selected for a higher resolution palynological analysis. There, a considerable change in the dinocyst taxa abundances is detected below and above the coquina. Along the entire core, several oscillations reflecting a negative correlation of *Spiniferites* and *Impagidinium*. Most of the encountered taxa have been recorded and described by Süto-Szentai (e.g.1982; 1990) from the Hungarian part of the Lake Ponnon but many of them, however, are invalid and emendations are needed.

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Morphology and distribution of the Miocene dinoflagellate cyst *Operculodinium*? *Borgerholtense* Louwye 2001, emend

Ali Soliman, Martin J. Head and Stephen Louwye

The extinct organic-walled dinoflagellate cyst *Operculodinium*? *borgerholtense* Louwye 2001 was first described from shallow-marine Miocene deposits of northern Belgium, and has since been documented from the Miocene of the eastern North Atlantic, North Sea, Austria, Hungary and Egypt. Conventional and confocal light microscopy and scanning electron microscopy are used to reveal new details of the archeopyle, wall structure, and ornament. The archeopyle is shown to have well-defined rather than rounded angles, a distinction we consider significant for the systematics of the genus. *Operculodinium*? *borgerholtense* is a euryhaline neritic species that was highly tolerant of

environmental stress, a feature consistent with its morphological variability. Present records indicate a tropical–subtropical to temperate paleoclimatic distribution. It ranges from upper Lower Miocene to upper Middle Miocene, and promises to be a useful stratigraphic marker particularly in neritic settings where adverse paleoenvironmental factors have excluded other species.

Comparative morphology and molecular phylogeny of *Apicoporus* gen. nov. - a new genus of marine benthic dinoflagellates formerly classified within *Amphidinium*

Sarah F. Sparmann, Brian S. Leander and Mona Hoppenrath

A broad range of uncultured morphotypes that were similar in morphology to *Amphidinium glabrum* Hoppenrath and Okolodkov were investigated. They were extracted from marine sandy sediments in the Eastern Pacific Ocean. In order to determine the number of distinct species associated with this phenotypic diversity, LM, SEM, TEM and small subunit ribosomal DNA sequence information from different morphotypes, including the previously described *A. glabrum*, were collected. Both comparative morphological and molecular phylogenetic data supported the establishment of a new genus, *Apicoporus* gen. nov., including a new species *A. parvidiaboli* sp. nov. *Apicoporus* is characterized by having amphiesmal pores and an apical pore covered by a hook-like protrusion; neither of these characters has been observed in other athecate dinoflagellates. Varying degrees of "horn formation", ranging from slight to prominent, were documented. Although the genus was previously interpreted to be obligate heterotroph, TEM and epifluorescence microscopy demonstrated that some cells had unusually small but otherwise typical dinoflagellate plastids. The presence of cryptic photosynthetic plastids in this benthic genus suggests that photosynthesis might be much more widespread in dinoflagellates than is currently assumed.

Common Interest, Different Jargon: the GSA Penrose Conference on Modern and Fossil Dinoflagellates, 1978

Karen Steidinger and William Evitt

Thirty years ago in Colorado Springs, Colorado a GSA Penrose Conference on Modern and Fossil Dinoflagellates was held to provide an informational exchange forum for biologists and geologists working on different life cycle stages of dinoflagellates. Recent evidence had suggested that resting cysts of modern dinoflagellates were morphologically similar or almost identical to fossilized cysts in marine strata. Basically, the "modern" represented biologists working on morphology, taxonomy, classification, evolution, distribution and ecology of extant species, while the "fossil" represented mainly paleontologists working on morphology, taxonomy, classification, evolution, and distribution of fossilized dinoflagellate cysts. The work of David Wall and Barrie Dale, then of the Woods Hole Oceanographic Institution, provided a conduit between the two scientific disciplines by finding living "fossils" in seawater and later showing that they were stages in the life history of a species. The biologists had their methods of study while the geologists had theirs, and modifications of both provided opportunities of discovery. They still do today. Approximately one-third of the conferees were biologists and two-thirds were geologists representing academia, government, and the oil industry. In all, the meeting was attended by 68 scientists from nine countries. There were 22 invited talks of 30 minutes or longer and 30 posters.

Since this was the first meeting of these two groups, neontologists and paleontologists, there was an important matrix of education where specific topics were chosen to establish common ground for discussions. Topics for invited speakers included: terminology, methods, and data on morphometrics (e.g., plate tabulation and paratabulation, plate overlap patterns), distribution (biostratigraphy, ecology of living forms), classification systems (two!), evolution, and life history. It is the life history of dinoflagellates that is the conduit between biology and geology. Dinoflagellates can have dimorphic to polymorphic life cycle stages and geologists were presumably studying resting stages. Not all dinoflagellates produce fossilizable cysts therefore the fossil record can be missing major phylogenetic groups and evolution based on the fossil record hard to present. In addition, some of the difficult-to-allocate microfossils currently known as acritarchs are almost certainly dinoflagellate cysts, while others very well may not be, the problem lying in the absence of definitive identifying characters. Recent studies have shown similarly nondescript cysts in life cycles of definitive dinoflagellates. Scientists such as Barrie Dale, Lois Pfiester, and Donald Anderson were at the meeting and went on to train many people in geological and biological techniques to isolate cysts from sediments or to experimentally induce excystment.

That this meeting was in essence DINO 1 is very significant because it provided the foundation for future research and models (as well as conferences). As an example, plate tabulation and paratabulation were extensively discussed. Many of the plate tabulation systems and models that were presented at this meeting were later published, e.g., the Eaton Tabulation System, Taylor-Evitt Tabulation System, Edwards Tabulation System, and a modified Kofoid System (Balech). In addition, imbrication patterns (Netzel and Gocht), and plate homologues (Bujak) were presented. All of these scientists were at DINO 1 except Enrique Balech who could not attend, but whose work was presented. These and other pioneers set the stage for decades of research and discovery. Some of the DINO 1 scientists are no longer with us, but their research is a legacy.

DNA Barcoding in dinoflagellates

Rowena Stern and Patrick Keeling

The challenges of using barcoding to identify as large and diverse a group as Dinoflagellates, with approximately 3000 known species, are considerable especially for fairly poorly catalogued especially in benthic and non-cultivatable species. Our first aim was to test whether DNA barcodes can really differentiate between dinoflagellate species and strains and therefore be used an effective tool to measure biodiversity. We collected almost 700 DNA samples from 15 culture collections representing 85 different species of dinoflagellates and have now obtained almost 700 barcode sequences from two genes, cytochrome oxidase I (COI) and the nuclear internal transcribed spacer (ITS). Comparing inter-generic, uncorrected pairwise distances for COI, we could distinguish between genera and species in most cases, which grouped together by pairwise distances (PWD) according to accepted phylogenetic relationships. However, for some cases, notably *Alexandrium*, a notoriously difficult group to differentiate morphologically, we found very little to no genetic distances between different species, a problematic issue given that a DNA barcode should uniquely identify each species. We then used ITS as an alternative barcode and found that it provided excellent species differentiation in those samples, using the same methods (165 fold increase in pairwise distances in *Alexandrium* species compared to those of COI) and therefore could be used as a second barcode in certain species, although paralogy exists and false clustering might arise for very divergence species. One problem of using culture collection samples, is that the sample may be a mixed population. Using our dinoflagellate specific primers, we were also able to reliably obtain barcodes from around 95 single cells, using only half the total DNA, making studies on species diversity much more accurate. The second aim was a "proof of concept" test of our barcodes to find how many unknown environmental dinoflagellate COI barcodes could be identified from our COI barcode database. We pooled a subset of 86 environmental COI barcodes from two coastal environments and found two thirds of environmental barcodes unidentified even at the genera level and only a fifth could be identified at the species level. There are whole clusters of environmental barcodes within the *Symbiodinium* supercluster that do not group with any barcode in our database, indicating the vast amount of unsampled biodiversity of dinoflagellates. Currently we are working on a larger environmental set from a single fjord inlet over two years and discuss challenges of using barcodes to separate strains, species and even genera to identify unknowns and methods to obtain an barcodes database that reflects the true biodiversity of dinoflagellates.

Molecular phylogenies of both host and cyanobiont of the genus *Ornithocercus* - Do they coevolve?

Yoshihito Takano, Mitsunori Iwataki and Kazumi Matsuoka

The heterotrophic dinophysoid genera *Ornithocercus*, *Parahistioneis*, *Histioneis* and *Citharistes* are well known as the most striking examples of symbiotic associations between dinoflagellates and cyanobacteria, which are found in the oligotrophic open oceans. In these genera both the cingular and sulcal lists are elaborated. Between the upper and lower cingular lists of *Ornithocercus* and *Parahistioneis* numerous extracellular symbiotic cyanobacteria, (cyanobionts; termed phaeosomes), are usually present. In *Histioneis* and *Citharistes* the more elaborated lower cingular list is made into a chamber, termed phaeosome chamber, in order to house the cyanobionts. In previous studies of several Dinophysoid genera associated with cyanobionts, a molecular phylogenetic analysis using 16S rDNA sequences and TEM observations revealed the genetic and morphological diversity of the cyanobionts and showed that several different sequence types and cell morphologies could be present in a single host. In both studies, however, the correspondence relationships between the hosts and the cyanobionts were unclear because the host dinoflagellates were not identified as a species level. Additionally, since

sequence data of the host dinoflagellates were not obtained due to difficulties in culturing, we have no knowledge on the phylogenetic relationships of them.

The aims of this study are to evaluate the current intrageneric taxonomy of the genus *Ornithocercus* based on both morphology and molecular data and to elucidate whether the host and the cyanobiont coevolve, or not, by means of molecular phylogenetic techniques. To infer the phylogeny both of the host and of the caynobiont, the 18S rDNA and the internal transcribed spacer (ITS) 1-5.8S rDNA-ITS2 (ITS regions) from the hosts and the 16S rDNA from the cyanobionts of *Ornithocercus magnificus, O. steinii* and *O. thurnii* were determined using a single cell PCR technique after observations and photographic records with a light microscope. In a molecular analysis using the 18S rDNA, sequences of *O. thurni* and *O. magnificus* were identical with one base pair substitution to those of *O. steinii*. In phylogenetic trees inferred from the ITS regions sequences *O. steinii* and *O. thurni* formed a clade, which clustered with *O. magnificus* as a sister.

Moreover, *O. magnificus* was separated into two clades; one possessed the posterior moiety of left sulcal list with surface reticulations and the other possessed it without them. Therefore, although each clade of *O. magnificus* could be considered as a distinct species, the final taxonomical treatment would be premature because of a low number of materials. In the case of the cyanobionts examined in this study, a single sequence type was determined from a single host. And phylogenetic trees inferred from the 16S rDNA sequences showed the same topologies with those of ITS regions sequences of the hosts. These results indicated the coevolution between the host and the cyanobiont, so far.

Holocene sea surface conditions in the northeastern Atlantic and western Mediterranean Sea: a dinocyst contribution

Jean-Louis Turon, Imene Rouis Zergouni, Laurent Londeix, Linda Rossignol and Marie-Helene Castera

There is increasing evidence of significant climate variability during the present interglacial. Nevertheless the paleoenvironmental oscillations are not yet clearly established for different timescale at short millennial, secular or longer term.

In the North-eastern Atlantic Ocean, numerous Informations about the variability of the surface climatic evolution during the Holocene are available. However results from different approaches and the synthetic work on the Holocene global général trend developed by Marchal et al. (2002) evidenced discordance between the reconstructions based on the different biomarkers (diatoms, planktic foraminifers, UK^{37}, diatoms). In the same way some conflicting results appears in still scarce studies from the Mediterranean basins.

In this context we present a new contribution based on the Dinocyst assemblage analyses established from four Holocene sequences: Two selected cores from the NE Atlantic MD 95 2015 (58°46'N /25°58'W; water depth 2630m) and CH 7702 (52°42'N/36°05'W; water depth 3744m) are located on the Gardar Drift along the Reykjanes Ridge and the Gibbs fracture respectively. In the Mediterranean Sea, two sites have been collected in the Alboran Sea between Spanish and N-African margins: core MD 95-2043 (36°08' N /02°37 W; water depth 1841 m) and ODP 976 (36°12N/04°18W; water depth 1020m).

From the two Atlantic cores sited in the N-E Atlantic our results show that the Holocene can be divided in three major periods. The first (11.5 Cal ky BP to 9 Cal ky BP) that is characterised by the development of *Nematosphaeropsis labyrinthus* corresponds to a slight warming and may be a high productivity period following the Younger Dryas cool event. From 9 to 6 Cal ky BP we observe the optimal development of *S.mirabilis* which characterizes a climatic optimum interrupted into the two sequence by a brief cool vent at ca 8 Cal Ka. This event could be the equivalent to the well knowed 8.2 event. *Operculodinium centrocarpum* and *P.dalei* revealing a significant cooling of the surface waters dominate the upper part of the sequences. It is interesting to note that this tripartite subdivision corresponds with the division in three phases which have been long time ago defined from continental proxy records: at the base of the Holocene the amelioration of Preboreal-Boreal, following by an hypsithermal, period and finally from 6ky a third phase corresponding to the Neoglaciation.

As regard to the Mediterranean sequences (Alboran Sea), the base of the Holocene start by the abrupt increase of *Impagidinium aculeatum*, the weak development of *S .mirabilis*, the clear decrease of *N. labyrinthus* accompanied by the significant development of *Brigantedinium* spp. By contrast with the evolution observed in the N-E Atlantic, there is no evidence in the middle part of the Holocene of a maximum warming equivalent to a hypsithermal. From 6 Ky Cal BP to the upper part the sequences are characterised by a continuous increasing of *S. mirabilis*, which become the dominant species of the dinocyst assemblage. Taking into account the development of the *S. mirabilis* and *I. aculeatum* warm association, we could conclude that we observe an opposite trend to the Atlantic domain with an

Holocene long term warming of the sea surface conditions in the Alboran Sea. However the imprint of the 8.2 event can be observed in the two domains.

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The structure of the upper water column in the eastern Nordic Seas during the last interglacial (MIS 5e), based on dinoflagellate cysts

Nicolas Van Nieuwenhove and Henning A. Bauch

Surface and last interglacial (MIS 5e) sediment from the Nordic Seas have been studied for their dinoflagellate cyst content. Supported by other proxies (ice rafted detritus (IRD), stable oxygen isotopes and planktic foraminiferal assemblages), the qualitative and statistical analyses of the dinocyst assemblages provide a comprehensive insight into the characteristics and evolution of the upper water column during MIS 5e. In the Norwegian Sea, the end of the Saalian deglaciation (Termination II) is marked by a clear drop in IRD and reworked dinocysts, immediately followed by an increase in absolute cyst abundances and the instalment of assemblages dominated by *Operculodinium centrocarpum*. This marks the beginning of a first interglacial interval, which is picked up in the dinocyst assemblages by the subtropical to temperate set of *Impagidinium* species. The results from the transfer functions suggest reduced sea-surface salinities for this first warm interval, presumably due to freshwater input by icebergs still drifting into the area, as suggested by significant amounts of IRD. Planktic oxygen isotopes have their lightest values during this interval. Another drop in IRD, towards near-zero values, marks the beginning of a second warm phase, regarded as the "real", fully marine interglacial optimum based on the coeval peak abundances of the dinocyst *Spiniferites mirabilis* s.l. and subpolar foraminifera. This late-interglacial optimum is in contrast with the early Holocene climatic optimum. Interestingly, the oxygen isotope values of this interval are heavier than during the preceding part of MIS 5e, but they compare well with the average Holocene values. The transfer function data show higher, near-present salinities for this interval, all suggesting the prevailing of a more modern-like type of surface circulation. After that, an increase in *S. ramosus* s.l., *Nematosphaeropsis labyrinthus*, the polar foraminiferal species *Neogloboquadrina pachyderma* (s), oxygen isotope values, and eventually also IRD, marks the transition from MIS 5e towards the MIS 5d stadial. A noteworthy feature of the entire MIS 5e is the constant higher abundance of *Bitectatodinium tepikiense* in comparison with the surface sample/latest Holocene. Together with reduced salinities and important seasonal gradients in salinity and temperature as suggested by the transfer function reconstructions, this points towards a more pronounced seasonality with enhanced stratification for the last interglacial. It thus seems as if Saalian deglacial meltwater had a prolonged influence on the structure of the upper water column of MIS 5e in the eastern Nordic Seas, and enabled a modern-like type of surface circulation to develop only late in MIS 5e, when summer insolation had already decreased markedly.

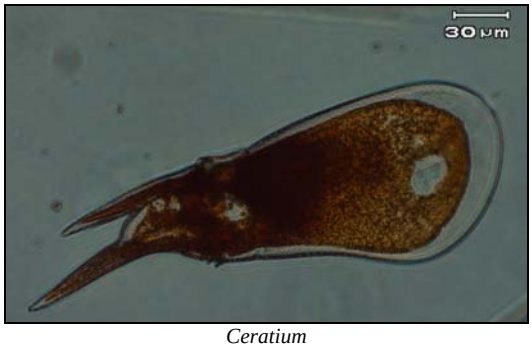
Dinoflagellates of the Cocos Island, Pacific of Costa Rica

Maribelle Vargas-Montero

The Cocos Island is located to 312 miles to the south of the Pacific coast of Costa Rica, situated among 05°32'29" N and 87°02'43" W. It is a national park and is protected as patrimony of the humanity. In these waters there have never been realized studies of the marine phytoplankton. One year ago, some expeditions have been realized for the collection of water and benthic samples, to determine the present phytoplankton in the waters. During the collection of the oceanographic ship Phoenix in the expedition CIMAR-COCO-I, we collected 58 water samples in different depths and there were realized cycles of 24 hours to determine the species of dinoflagellates. We found a great variety of planktonic and benthic dinoflagellates, of which they have found 75 species of dinoflagellates, belonging principally to 5 genera, *Ceratium* with 20 species, *Protoperidinium* with 8 species, *Dynophysis* with 7 species, *Ceratocorys* with 2 species and *Ornithocercus* with 3 species. The genus that presented major diversity of species was *Ceratium*, being big enough organisms and dominating the water column up to 20 meters on depth. Likewise the most abundant genera besides *Ceratium* was *Ornithocercus*, the latter always was present in the water samples, principally during the night. All nights in the waters of the Cocos Island is observed the phenomenon of bioluminescence, reason for which the species of *Ornitocercus* and *Ceratocorys* always were present in the samples.

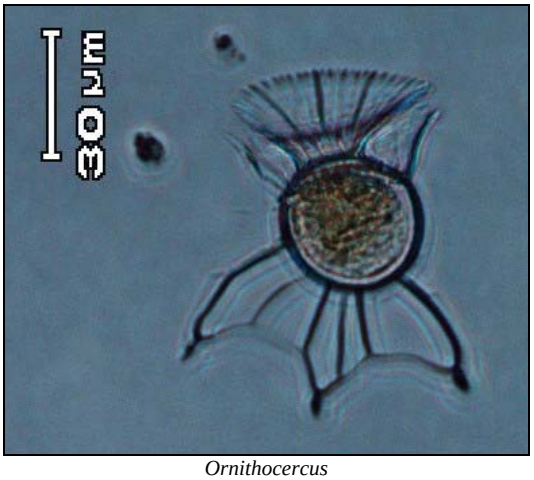
Many of the species observed have never been reported in coastal samples of Costa Rica, since this island is merely oceanic and receives the influence of the waters from the south hemisphere, for what the majority of the opposing organisms are

merely oceanic. In some of the observed samples we found great quantity of *Ostreopsis lenticularis*, this organism is the dominant one, inclusive in samples taken to 6 and 12 meters in depth on macroalgae. Only in one of the samples was two cells of naked organisms belonging to the genera *Gymnodinium*, all other opposing species are armed species. This is the first preliminary study that is done for the phytoplankton in the waters about the Cocos Island of Costa Rica, principally for the long distance of this island to the continent.



Ceratium

Ornithocercus



Ornithocercus

Temporal distribution of organic-walled dinoflagellate cysts in recent marine sediments from the Gulf of Tehuantepec, South Pacific of Mexico

Luis Fernando Vásquez Bedoya

The temporal abundance distribution of recent organic-walled dinoflagellate cysts was studied in a 18 cm long sediment core collected in the coastal zone of the Gulf of Tehuantepec, Mexico. ^{210}Pb and ^{137}Cs-derived sedimentation and mass accumulation rates in the core were determined to vary from 0.033 to 0.209 cm y^{-1} and from 0.05 to 0.29 g cm^{-2} y^{-1}, respectively. Twenty-three cyst taxa were identified (*Brigantedinium* spp., *Polysphaeridium zoharyi, Bitectatodinium spongium, Spiniferites delicatus, Quinquecuspis concreta, Echinidinium transparantum, Operculodinium centrocarpum, Selenopemphix quanta*, *Echinidinium granulatum, Echinidinium aculeatum, Protoperidinium americanum, Echinidinium delicatum, Selenopemphix nephroides*, Cyst of *Protoperidinum stellatum, Lingulodinium machaerophorum, Islandinium* spp., *Votadinium spinosum*, *Polykrikos kofoidii, Pentapharsodinium dalei, Tuberculodinium vancampoe, Spiniferites mirabilis, Votadinium calvum and Nematosphaeropsis labyrinthus*). The assemblages included cysts of both phototrophic and heterotrophic species, with variation of their respective abundance reflecting changes in the trophic structure of the upper water mass, especially after 1950, with a decrease from ~30% to 15% of phototrophic species, likely as a response to pollution (including cultural eutrophication) created by the industrial development of the adjacent coastal zone. *Brigantedinium* spp., *Polysphaeridium zoharyi* and *Bitectatodinium spongium*, were the dominant species found in the core and are most likely influenced by the seasonal upwelling that characterize the study area. A Canonical Correspondence Analysis (CCA) considering dinocyst relative abundances and geochemical parameter concentrations (such as trace metals and nutrients) has shown that two main groups of parameters that explain the 49% of the variance in the dinoflagellate data. The first one included the concentrations of $CaCO_3$ (that results from in situ primary production) and P_t, Cd, Mn and N_{org} (that are elements commonly associated to upwelling areas). The second group included Ag, Hg, Pb, V (which were related to anthropogenic sources), as well as Al and Li (as indicators of crustal origen). Species associated with the first cluster included cyst of *Pentapharsodinium dalei, Votadinium calvum, Lingulodinium machaerophorum, Tuberculodinium vancampoe, Operculodinium centrocarpum* and

Spiniferites delicates which are common species in upwelling areas; whereas the second group included cysts of *Protoperidinum stellatum* and *Polykrikos* Type *kofoidii* which are species reportedly associated to anthropogenization sources.

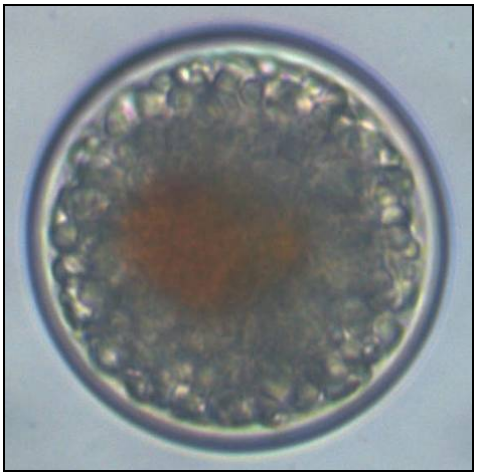
New insights into the life-cycle of two species within the Family Goniodomaceae, *Alexandrium pseudogonyaulax* and *Fragilidium* sp.

Vera Veloso, André Grilo and Ana Amorim

Cultures of *Alexandrium pseudogonyaulax* were obtained by germination of typical paratabulated cysts isolated from estuarine sediments in the NW coast of Portugal and from single cells isolated from the S coast. Cells were cultured in f/2 without silica (salinity 35) at 19ºC and 14:10 light: dark cycle. Sexual reproduction was recorded in both clonal and non-clonal cultures, at very low culture density, during the ligh period, only a few days after cyst germination or initiation of a new clonal culture. Vegetative cell division was observed to occur inside the non-motile parent cell (division cyst), Division cysts may originate 2 or 4 daughter cells. In the first case the resulting cells were similar to the parental cell, and a new culture could be obtained by single cell isolation. When 4 daughter cells were produced, cells were smaller than the parental cell and had a lighter pigmentation due to the concentration of the chloroplasts in the cell centre. When the 4 cells were transferred to a new culture vessel, isolated or in group, a new culture could never be established, suggesting these maybe gametes. Both isogamy and anisogamy were observed to occur. Cysts produced in culture showed the typical paratabulation of the species and a mandatory dormancy period of more than 4 months.

Cultures of a non-flagellate photosynthetic planktonic stage isolated from Lisbon Bay, central Portugal, were established using the same culturing conditions as above. Plate tabulation allowed the assignment of the species to the genus *Fragilidium*. The non-motile stage is characterised by having a halo surrounding the cell which separates the thecal plates from the protoplast. The chloroplast or chloroplasts are pigmented brown and respond to light stimulus by moving to the cell centre. In culture the non-motile stage was the dominant stage. Motile cells were only visible in the first hours of the light cycle in young cultures, but became more frequent and increased in number with the ageing of the culture. Both motile and non-motile cells were observed in 3 markedly different sizes. The smaller cells were less pigmented and yellow in contrast to the dark brown of the other cell types. Vegetative cell division was only observed to occur in the non-motile stage. Cell division occurred within the mother cell membrane resulting in 2 or 4 cells. When 2 cells were produced the flagella of the daughter cells were usually visible inside the mother cell, but when cells erupted two things were observed to occur: (1) 2 cells swim out, initially as a short chain, or (2) the 2 cells rapidly loose their flagella, become immotile, and the cell wall is seen to detach from the protoplast giving a non-motile vegetative cell similar to the parental cell. When 4 cells were produced a two step division was observed. First, 2 cells were produced, gaining each an independent membrane. Each of these then divided originating 2 daughter cells that swam out and behaved as the 2 cell division described above. Several sexual stages could be identified. Gamete pairs were observed during the dark cycle always with anisogamy. The planozygote could be identified by the presence of 2 longitudinal flagella. A resting cyst with a smooth wall develops from a non-motile cell, where the theca is not seen to be detached from the protoplast that shows evident nuclear cyclosis two or three days before cyst maturation.

Fragilidium - vegetative cell



Fragilidium - cyst

Late Quaternary dinoflagellate cysts and pollen from Porcupine Basin (IODP 307, Hole 1318B): indication of small-scaled climate variations

Koen Verhoeven and Stephen Louwye

High resolution palynological analysis of latest Quaternary sediments of Hole 1318B (IODP Leg 307) revealed the presence of a well-preserved assemblage of marine and terestrial palynomorphs. Thirty five samples were analysed for dinoflagellate cysts and pollen, and a total of at least 350 specimens were counted. A statistical minimum for the pollen sum was not always obtained, hence the limited vegetational information. The total pollen sum is situated between 34 specimens in pollen-poor sediments, and 1250 specimens in pollen-rich sediments. Wind is by far the most important transportation medium for the terrestrial palynomorphs, since most pollen are bisaccate (mainly Pinus). A total of 52 different pollen types are recorded, of which 47 can be attributed to angiosperms. This pollen is brought into the depositional area through river transport and currents. The relative high number of pollen number is not surprising given the location of the drill site, approximately 100 km off southwest Ireland.

Five dinoflagellate zones indicative for colder sea surface temperatures could be directly recognised in the uppermost 10m of Hole 1318B. Two cold-water species are especially abundant in these zones: *Bitectatodinium tepikiense* and *Operculodinium centrocarpum* sensu Wall and Dale. *Bitectatodinium tepikiense* is the dominant thermophilic species during warmer intervals, and is almost absent during glacial times. Transfer functions executed with the program 3PBase and based on MAT (Modern Analogue Technique) made it possible to detect not five but a total of eight colder intervals.

In general, the eight colder intervals alternate cyclic with warmer periods of a comparable duration and precede the Holocene climate amelioration.

Plio-Pleistocene land-sea correlations in the Icelandic region: a palynological approach - First results

Koen Verhoeven and Stephen Louwye

The first results of a palynological analysis of Pliocene and Pleistocene deposits from northern Iceland are presented. The aim of the study is to quantify the effects of the onset of the late Pliocene cooling and the beginning of the Pleistocene glaciations on terrestrial and marine palynomorphs. Pliocene marine and terrestrial palynomorphs are analysed from the well-exposed Tjörnes Beds in northern Iceland. Next to the climatic information, a secondary aim of the study is to have a better biostratigraphical insight in the oldest exposed sediments in Tjörnes who are probably of Miocene age. During the summer of 2007, a more than 1000m thick section in Iceland was logged and sampled for palynological analysis. Previous paleontological and palaeoecological studies on this section comprise analysis with molluscs and ostracods and indicate deposition in a shallow marine environment. The section was deposited in less than 4.3 Ma and points towards high sedimentation rates. As a consequence, the concentration of marine palynomorphs (mainly dinoflagellate) and pollen is low. However, the proximity of the land gives a continuous input of sufficient pollen. A core from the island of Flatey, a few kilometres further down the paleo-shelf, is the first step in the land-sea correlation. Correlation between this drilling and the Tjörnes section was facilitated through geochemical distinctive ash layers. Test samples from the Tjörnes Beds and from the Flatey core show a moderate till good preservation of dinoflagellate cysts. In contrast with the marine sediments of the land section, dinoflagellate cysts are abundant and the pollen scarce. A possible explanation lies is the different depositional environments and possible oxidation of the land section. Further research must clarify this issue.

The deepest depositional environment for the land-sea reconstruction is represented in ODP Drilling Leg 151 Hole 907A and ODP Drilling Leg 162 Hole 985A, both located on the Icelandic Plateau. These two cores lie in the closest vicinity of the Iceland section and have an excellent magnetostratigraphic record and sediment recovery. The palynological analysis of both cores will complete the land-sea correlation. Ice cover in times of glaciations will be detected in the poor and partly reworked dinocyst assemblages. Interglacial assemblages on their hand will be characterised by dinoflagellate cysts as well pollen because of the relative close vicinity of the island.

Holocene dinoflagellate cysts as salinity indicators from the southwestern Black Sea

Thomas Verleye, Kenneth Mertens, Stephen Louwye and Helge Arz

Dinoflagellate cysts are used as a proxy for the reconstruction of the salinity variations during Holocene times in the southwestern Black Sea. Core GeoB 7625-2, located 50 km northeast of the mouth

of the Sakarya River, was sampled with a 200 year resolution between 0.25 ka BP – 7.8 ka BP. In the lower part of the core, some extra crucial intervals were sampled with a higher resolution for the determination of the reconnection between the Black Sea and the Sea of Marmara. The drastic change in the dinoflagellate cyst assemblage – from a fresh-brackish water to saltwater association – is observed between ~9.6 and ~8.1 ka BP, which is earlier than observed in the dinocyst studies of e.g. Marret *et al.* (in press), Mudie *et al.* (2001) and Wall & Dale (1973). This could indicate a diachronic salinification of the Black Sea. The fresh to brackish water indicator species are *Spiniferites cruciformis* form 1-4 and *Pyxidinopsis psilata*, while the most important saltwater species are *Lingulodinium machaerophorum* and cysts of *Pentapharsodinium dalei.* The first occurrence of euryhaline species took place synchronous with a sea level rise and an increase in productivity. The process length of *L. machaerophorum*, a salinity proxy, indicates a gradual salinity increase. This assumes a gradual reconnection between the Black Sea and the Sea of Marmara, which conflicts with the catastrophic flood (Noah's Flood Hypothesis) introduced by Ryan *et al.* (1997, 2003). The 500 to 800 year cycles observed in the sedimentary record by Lamy *et al.* (2006), and related to the North Atlantic Oscillation, were not only recorded by us in the salinity proxy but also in dinoflagellate cyst abundances (productivity). The observed productivity changes are furthermore related to the sedimentation rate: the increase in precipitation in Anatolia possibly results in a higher sediment discharge leading to a better preservation of the organic-walled microfossils. This makes it difficult to determine whether the fluctuations of the dinocysts/gram ratio are the result of fluctuations in productivity or are an artefact due to changes in the sedimentation rate. Furthermore, it is shown that *Peridinium ponticum*, a species restricted geographically to the Black Sea, is a good proxy for the reconstruction of Holocene salinity variations since its relative abundance fluctuates synchronous with the process length variations of *L. machaeorophorum*.

History of Florida East Coast *Karenia brevis* Red Tides, with Emphasis on the Unusual 2007 Bloom

Jennifer Wolny, Earnest Truby and Jacob Tustison

Blooms of the toxic dinoflagellate *Karenia brevis* occur commonly in the eastern Gulf of Mexico. Here, prevailing winds and currents can move blooms from offshore to inshore and impacts to beach goers and coastal communities are more acute. Less common, however, is the occurrence of *K. brevis* blooms on Florida's east coast. In 1946 and 1947 *Karenia brevis*, the organism responsible for Florida red tides and associated human and animal health impacts was identified from a bloom occurring off the central west Florida coast. In 1946 respiratory irritation and fish kills were reported on the Jacksonville coast, suggesting that the red tides could occur on Florida's east coast as well. However, it wasn't until 1972 that the transport of *K. brevis* from the west Florida coast to the east Florida coast via the Gulf Stream System was documented when red tide came inshore in the St. Lucie and Martin County areas. Transport of *K. brevis* from the west Florida coast to the east Florida coast has since been documented in 1977, 1980, 1983, 1990, 1997, 1999, and 2006 and persisted for a month or less. The Gulf Stream System, which included the Loop and Florida Currents and the Gulf Stream, plays a major role in the distribution of red tide.

In September 2007 reports of respiratory irritation and fish kills were received from the Jacksonville area. Water samples collected from these areas indicated a bloom of *K. brevis*. For the next 4 months, *K. brevis* was found along the coast and in the intercoastal waterways from Jacksonville to Jupiter Inlet. This event represents the longest and most extensive red tide the east coast of Florida has experienced to date. The dynamics, extent, as well as impacts of east coast Florida *K. brevis* red tides will be discussed.

Barremian-early Cenomanian nonmarine micro-phytoplankton from the north part of Hailar basin, Inner Mongolia, China

Qiao Xiu-Yun, Shu-Zhi Wang, Tao Song, Yan-Bin Xu and Guo-Bin Zhang

A deep oil well was drilled in the North Hailaer Basin, Inner Mongolia, China, and Cretaceous sediments with an accumulative thickness of about 3000m were recovered. Early Cretaceous formation has been subdivided in ascending order into five formations: Tamulangou, Tongbuomiao, Nantun, Damuoguaihe and Yimin Formation. The late cretaceous is represented by the Qingyuangang Formation. Two oil wells from North Hailaer Basin have been investigated for this study. The samples lithology is mainly green ash (deep and shallow), celadon mudstone, powder sand and mudstone. Fifty samples were prepared for palynological analyses. Palynomorphs are composed mainly by dinoflagellates, chlorophytes (*Botryococcus braunii*)

and acritarchs. The present paper records 24 species belonging to 16 genera. According to vertical changes in the microtoplankton flora, three assemblage zones of the early Cretaceous were defined and organized in stratigraphic order. The first assemblage, from the Nantun Formation, is characterized by the predominance of dinoflagellates, chlorophytes and acritarchs, and it is dominated by *Protoellipsodinium fibratum* and *Dinogymniopsis daqingensis*. The second assemblage is marked mainly by the dinoflagellates *Protoellipsodinium fibratum* and *Dinogymniopsis daqingensises,* and the chlorophytes *Scenedesmus bifidus*. *Protoellipsodinium fibratum* and *Dinogymniopsis daqingensis* are relatively abundant (they are not normally found together, but are found together occasionally in anomalous facies), while *Parabohaidina granulata, Zhongyuandinium* sp., *Nyktericysta* sp.1 and *Tetranguladinium conspicuum* are less abundant. Chlorophytes are well represented with the dinoflagellates *Scenedesmus bifidus, S.*cf.*dimorphus* and *Tetraedron* sp. and are well-preserved and accompanied by *Pediastrum boryanum* and *Tetrastrum minor*. *Leiosphaeridia hyaline* and the acritarchs *L. taxodiformis* are also relatively abundant with rare *Psiloschizosporis parvus*. Relatively abundant *Protoellipsodinium fibratum* and *Pediastrum boryanum* are found together in the Hong D-3 well, but they are not found in association with *Scenedesmus*. On the opposite, *Dinogymniopsis daqingensis* with abundant *Scenedesmus* and *Tetraedron* sp. are found in association in the Hong D-1 well. However, they are not found in association with *Pediastrum boryanum*. This is probably the result of different environmental conditions at that period, such as water depth, pH, etc., which is reflected by the different dinoflagellate genera and species together with chlorophytes which have different ecological requirements .The possible age is Barremian. The third assemblage, characterized by *Nyktericysta, Vesperopsis* and *Leiosphaeridia*, is found within the top two Members of the Damuoguaihe Formation in the Hong D-1 Well. In this assemblage, dinoflagellates are rare, while acritarchs increased and chlorophytes are less abundant. It is marked by the presence of *Nyktericysta* sp., *Vesperopsis* sp.and *Leiosphaeridia* sp., which is entirely different compared to the previous assemblage dominated by *Protoellipsodinium fibratum* and *Dinogymni*opsis daqingensis. The dinoflagellates *Nyktericysta* sp. and the *Vesperopsis* sp. occur sporadically in this assemblage, with occasional *Vesperopsis granulatalata. Bosedinia* sp. and *Nyktericysta beierensis*. The acritarchs *Leiosphaeridia* sp. and *Granodiscus granulatus* also occur sporadically, accompanied by the chlorophytes *Scenedesmus* cf. *dimorphus*. This assemblage is dated to the Early Cretaceous, probably at the Barremian-Aptian transition. The *Dinogymniopsis tuberculata - D. granulata* assemblage is found in Members-2 of the Damuoguaihe Formation in Hong D-1 well. The latter is composed almost inclusively by the dinoflagellates *Dinogymniopsis tuberculata* and *D. granulate*, the latter being the most abundant. This suggests an age of the earlier period of the Late Cretaceous, possibly the earlier period of the Cenomanian. In summary, the Barremian-Early Cenomanian nonmarine microphytoplankton from North Hailaer Basin, Inner Mongolia, China, has the following characteristics: (1) Dinoflagellates are mostly represented by proximate, as well as cavate-proximate and chorate cysts (having shorter or relatively dense thin processes provides an advantage in certain types environments; (2) Dinoflagellates are usually in association with several small chlorophytes (*Scenedesmus, Pediastrum, Tetraedron* and *Tetrastrum*). *Pediastrum*, which is usually thriving in ponds and lakes, is eurythermal freshwater algae (4-36°C), and thus a freshwater indicator. *Scenedesmus* is spread in lake, pond and usually in symbiosis with *Pediastrum*, which enrich quiet, acid and polluted ponds and lakes. *Tetraedron* and *Tetrastrum* are also frequent freshwater algae in ponds and lakes. Their fossil data are however fewly reported in the literature, e.g., in fresh water sediment of south England and United States. (Batten and Lister, 1988a, 1988b) showed that Barremian- Early Cenomanian microphytoplankton assemblages from North Hailaer Basin reflect nonmarine environment.

Feeding by phototrophic red-tide dinoflagellates on the marine ubiquitous diatom Skeletonema costatum

Yeong Du Yoo, Nam Seon Kang, Jae Yoon Song, Woongghi Shin, Wonho Yih and Hae Jin Jeong

We investigated interactions between phototrophic red-tide dinoflagellates and the ubiquitous diatom *Skeletonema costatum*. To explore whether dinoflagellates are able to feed on *S. costatum*, we carefully observed inside the protoplasms of target dinoflagellate cells under an epifluorescent microscope and transmission electron microscope (TEM) after adding living prey cells. In addition, we measured ingestion rates of the common phototrophic dinoflagellates *Prorocentrum micans* and *Gonyaulax polygramma* when feeding on *S. costatum*. We also calculated grazing coefficients by combining field data on abundances of *P. micans* and *G. polygramma* on co-occurring *S. costatum* with

laboratory data on ingestion rates obtained in the present study. All phototrophic dinoflagellate predators tested (*Akashiwo sanguinea*, *Amphidinium carterae*, *Alexandrium catenella*, *A. tamarense*, *Cochlodinium polykrikoides*, *G. polygramma*, *Gymnodinium catenatum*, *G. impudicum, Heterocapsa rotundata*, *H. triquetra*, *Lingulodinium polyedrum*, *Prorocentrum donghaiense, P. micans*, *P. minimum*, *P. triestinum,* and *Scrippsiella trochoidea*) were able to ingest *S. costatum*. With increasing mean prey concentration of ca. 1-3,440 ng C ml^{-1} (40-132,200 cells ml^{-1}), the ingestion rates of *P. micans* and *G. polygramma* on *S. costatum* continuously increased. At the given prey concentrations, the maximum ingestion rates of *P. micans* and *G. polygramma* on *S. costatum* (0.344--0.345 ng C $grazer^{-1}d^{-1}$; 13 cells $grazer^{-1}d^{-1}$) were almost same. The maximum clearance rates of *P. micans* and *G. polygramma* on *S. costatum* were 0.165 and 0.020 µl $grazer^{-1}h^{-1}$, respectively. The calculated grazing coefficients of *P. micans* and *G. polygramma* on co-occurring *S. costatum* were up to 0.383 $h^{-1}$and 0.214 h^{-1}, respectively (i.e. up to 32 % and 19 % of *S. costatum* populations were removed by *P. micans* and *G. polygramma* populations in 1 hour). The results of the present study suggest that *P. micans* and *G. polygramma* sometimes have a considerable grazing impact on populations of *S. costatum.*

The relationships of winter PSP toxins with cell density and cyst flux of *Alexandrium* in Dapeng Cove of Daya Bay, South China Sea

Zhao-Hui Wang, Yu Cao and Yujuan Zhang

Sediment traps were set in shellfish cultural area and caged fish area in Dapeng Cove of Daya Bay, South China Sea. Scallop (*Chlamys nobilis*) and mussel (*Perna viridis*) were cultured at the same time from April 2005 to June 2006. Changes in cell density and cyst flux of *Alexandrium* spp., Paralytic Shellfish Poisoning (PSP) contents in shellfishes were measured during the survey in order to understand the relationships between population size of *Alexandrium* (vegetative cell and cyst) and PSP contents, and to reveal the resource of high content of PSP toxin in this area in winter. Both vegetative cell and cyst of *Alexandrium* sporadically occurred, however a high peak of cell density was observed on February 2006, with a maximum of 6.03×10^5 cells/L. Meanwhile, cyst formation reached its maximum level of 4.56×10^4 cysts/m^2 d just following the peak abundance of motile cell. The PSP contents in shellfish were generally below the limit level suggested by FAO of UN (4 MU/g_{tissue}) in most samples, whereas it were higher in winter, and a maximum of 72.2 MU/g_{tissue} was detected in mussel samples from shellfish cultural area in January 2006, just after a peak abundance of *Aexandrium* vegetative cells and cysts. The toxins mainly accumulated in peptic of the shellfish, the maximum toxin content in peptic was high up to 350.4 MU/g_{tissue}. Statistical analysis showed significant exponential positive relationships between toxin content and vegetative cell density and cyst flux. From the results, it could be suggested that abundance of vegetative cells and cysts of *Alexandriu*m influence the toxin content directly and therefore resulte in the high winter level of PSP toxin in this area.

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